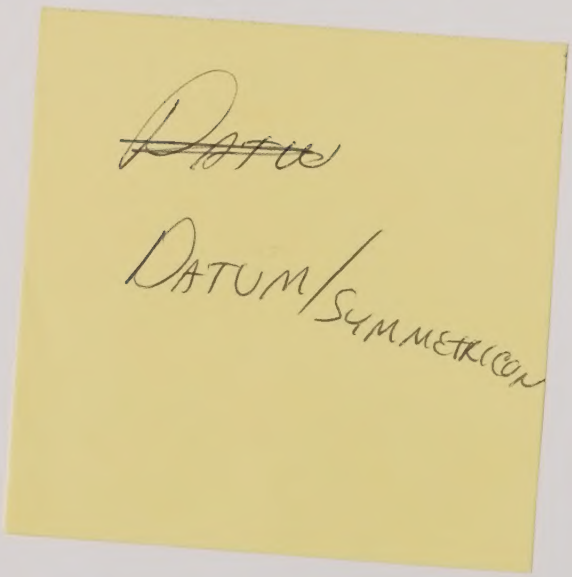
OC. – PP1
Laboratories
AN – 9048

Symmetricom®

MP MASTER
MA35132


~~RATIO~~
DATUM/SYMMETRIEN

OPERATING MANUAL

MODEL FTS 4040A/RS

CESIUM TIME AND FREQUENCY STANDARD

Option Coverage: 063, DS1 Frequency Synthesizer (see Appendix C)
064, CEPT Frequency Synthesizer (see Appendix D)
003, 1 PPS (see Appendix E)

FTS Part Number: 08518-001-00000
Revision: AD

Printed: 14 September, 1999
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OPERATING MANUAL ADDENDUM

Applicable to the following:

MODEL	*MANUAL*	*PART NUMBERS*
PRS50	N/A	11271
DCD	N/A	08949
DCD	N/A	08950
3310	N/A	11227
5045A	N/A	08499
4065A	08518	08490
4040A/RS	11846	08832

Rev. -
June 23, 1999

The serial number label applied at the factory to the units above contains more information that is necessary for the electronic identification of the unit.

The unit identification (electronically stored within the unit) will be the last five digits of the serial number, which is physically marked on the unit's label.

The serial number label is a 10 digit, unique number

YYWWXXXXXX

Where:

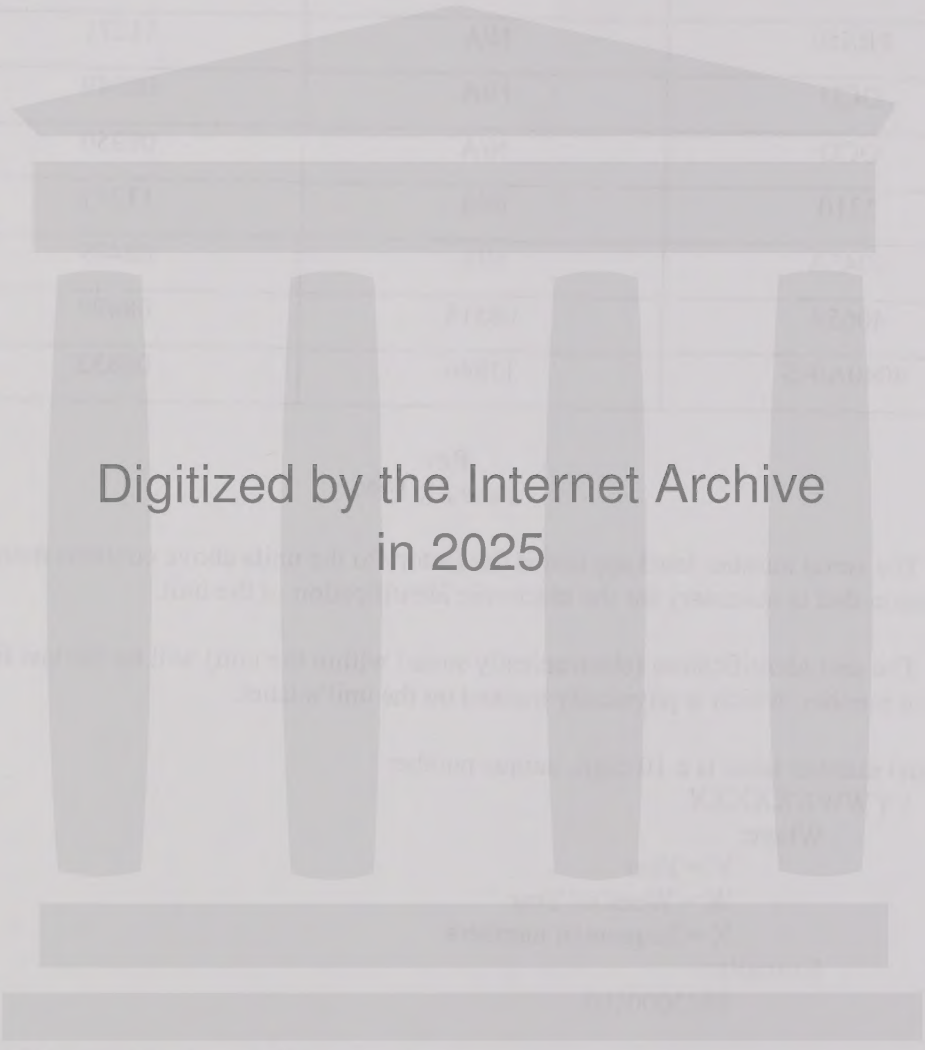
Y = Year
W = Week of Year
X = Sequential numbers

Example:

9923000105

Serial number was assigned on the 23'rd week of 1999 (AKA Lot Date Code, LDC) and have a sequential number of 000105.

When communicating with the unit the serial number in the example above is 00105.



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SECTION 1

GENERAL INFORMATION

SECTION 1. GENERAL INFORMATION

1.1 INTRODUCTION

The FTS 4040A/RS Cesium Beam Frequency and Time Standard is an accurate and stable frequency and time reference with microprocessor control. This manual contains detailed performance and installation specifications (Section 1), operating procedures (Section 2).

1.2 SUMMARY DESCRIPTION

The FTS 4040A/RS Cesium Time and Frequency Standard is a primary frequency and time reference with microprocessor control. The major function of the FTS 4040A/RS is to produce accurate, stable, and spectrally pure sinusoidal signals, and precise timing signals. To accomplish this, a cesium beam tube resonator is used to stabilize the output of a quartz crystal oscillator.

A microprocessor is used to perform the following tasks:

- Digital demodulation and integration of the servo loop signals
- Monitoring of system parameters
- Control of adaptive servos
- Diagnostic functions to aid in troubleshooting

The FTS 4040A/RS operates from 90/240 Vac or 22 to 56 Vdc.

A complete list of performance characteristics is provided in Table 1-1. Figures 1-2 and 1-3 are characteristic curves of the rf output signals in the frequency and time domains. Table 1-2 lists recommended test equipment for operating and performance checks, troubleshooting, and alignment.

1.3 INSTRUMENT IDENTIFICATION

A slash (/) and a three-digit number, following the model number (4040A/RS) specifies an option that is supplied within the instrument. Section 1.4 is a list of available options.

1.4 UNIT CERTIFICATONS

The 4040A/RS conforms to the following certifications:

FCC: This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart B of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.

UL: This equipment is UL registered per UL1950 and has been tested for continuous operation at ±10% of the specified operating voltages.

CE: This unit is declared to conform to the following standards:

EN 55022 1994, Class A for conducted and radiated emissions.
GN 50082-1 1992 to include IEC 801-2: 1991, 801-3: 1984, 801-4: 1988
EN 60950-1/DIN VDE 0805.

TABLE 1-1 SPECIFICATIONS, FTS 4040A/RS (at 25 °C unless otherwise specified)

PERFORMANCE

ACCURACY [1]	<2e-12	
REPRODUCIBILITY	<1.2e-12	
SETTABILITY (Frequency)	Resolution: 1×10^{-15} Range: $\pm 1 \times 10^{-9}$	
FREQUENCY CHANGE		
Over operating temperature	$< 5 \times 10^{-12}$	
Under dc magnetic field (2 gauss dc; ac, 50, 60, 400 Hz)	$< 2 \times 10^{-12}$	
OPERATING TEMPERATURE RANGE	0 to 50 °C	
STABILITY $\sigma_y(\tau)$		
Averaging Time (τ)		
1 s	$<2.0 \times 10^{-11}$	
10 s	$<2.1 \times 10^{-11}$	
100 s	$<5.0 \times 10^{-12}$	
1,000 s **	$<1.6 \times 10^{-12}$	
10,000 s **	$<5.0 \times 10^{-13}$	
SSB PHASE NOISE £(f)		
(1 Hz Bandwidth)		
Offset from Carrier £(f)	@ 10 MHz	
1 Hz	-90 dBc	
10 Hz	-120 dBc	
100 Hz	-140 dBc	
1000 Hz	-145 dBc	
SPECTRAL PURITY	@ 10 MHz	@ 5 MHz
Harmonics	<-40 dBc	<-40 dBc
Spurious Signals	<-80 dBc	<-80 dBc
WARM-UP TIME *	30 minutes	

[1] 100% verified and calibrated against FTS in-house standard.

* Note: If the FTS 4040A/RS has been in storage for an extended period, the warm-up time may be greater than specified.
** Note: Excluding environmental effects.

OUTPUTS

SINUSOIDAL OUTPUT	
Rear Panel (standard 1 ea)	1, 5, 10 MHz (one each on rear panel)
Amplitude	1.0 Vrms into 50 ohm load
TTL OUTPUTS	0.1, 1, 5, 10 MHz (user selectable)
Rear Panel	1.544 MB/s, Option 063
	2.048 MB/s, Option 064
BALANCED OUTPUTS	
Rear Panel	1.544 MHz, Balanced DS1, Option 063
	2.048 MHz, Balanced CEPT, Option 064

TABLE 1-1 SPECIFICATIONS, FTS 4040A/RS (at 25°C unless otherwise specified) (cont'd)

CONTROLS

REMOTE (RS232)	
Loop Time Constant	0.1 to 100 s
Square Wave Output	0.1, 1, 5, 10 MHz
Phase/Time Adjustment	± 1 to 10,000 x 10^{-9} s
Frequency Adjustment	± 1 x 10^{-15} to 10^{-9}
MONITORS	
Remote - RS232 Bus	Section 2, para. 2.6

GENERAL

POWER REQUIREMENTS		AC	DC
Operating Voltage		90 to 132, 180 to 265 Vac	±22 to 56 V dc
Frequency Range		47 to 63,400 Hz	N/A
Power	(operating)	110 VA, 65 W	60 W
	(warm-up)	140 VA, 90 W	90 W
MATING CONNECTORS			
Rear Panel			
AC Line Input		Belden #17250 Power Cord	
External DC Input		#6 screw terminal block	
15 Pin D-Connector		15 Pin D-Connector (DA15S-FO, ITT Cannon)	
		Mating Connector (DA15S)	
RF Outputs		BNC	
FUSES			
AC Line Input	@ 110 V	T2 A, 5 mm x 20 mm	
	@ 220 V	T0.8 A, 5 mm x 20 mm	
Ext DC Input		F3.15 A, 5 mm x 20 mm for Europe	
Ext DC Input		F3.0 A FB, 5 mm x 20 mm for US	
DIMENSIONS (maximum)			
Height		5.22"	
Width (excluding rack mounting ears)		19.00", 17.31" without mounting ears	
Depth (including handles)		17.30"	
Shipping Dimensions		25" x 31" x 11"	
WEIGHT		45 lbs	
Additional Weight for Container		34 lbs (for plywood container)	
NOTE: Shipping instructions may change without notice or change to this manual		12 lbs (for cardboard container)	

ENVIRONMENT

TEMPERATURE, OPERATING	0 to 50°C
TEMPERATURE, NON-OPERATING	
Storage	-40 to +50°C
Short-term	-40 to +75°C
HUMIDITY, OPERATING	95% up to 50°C
MAGNETIC FIELD	0 to 2 gauss

OPTIONS

001	Carrying Case
063	1.544 MHz DS1 Balanced and TTL Outputs
064	2.048 MHz CEPT Balanced and TTL Outputs
075	Extended Life Tube

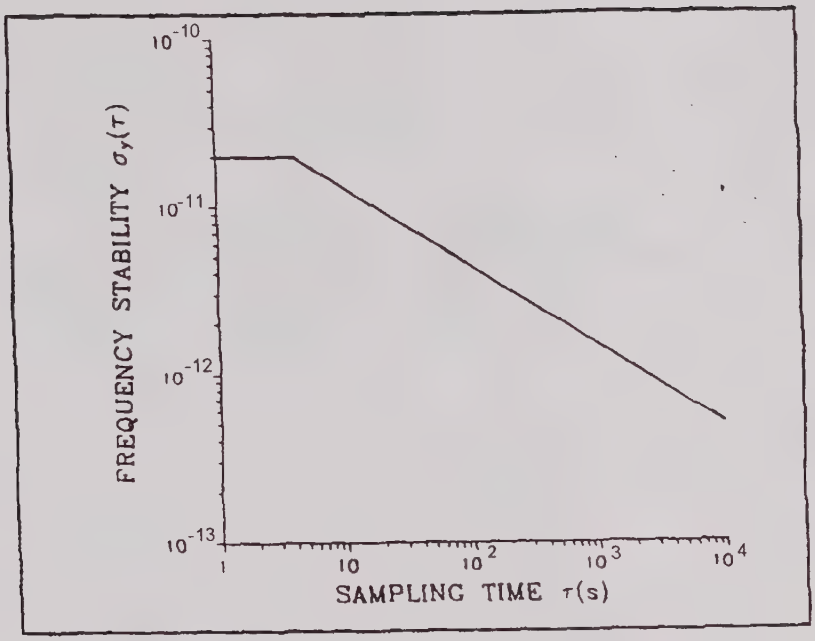


FIGURE 1-2 FREQUENCY STABILITY (5 second time constant, 2nd order loop)

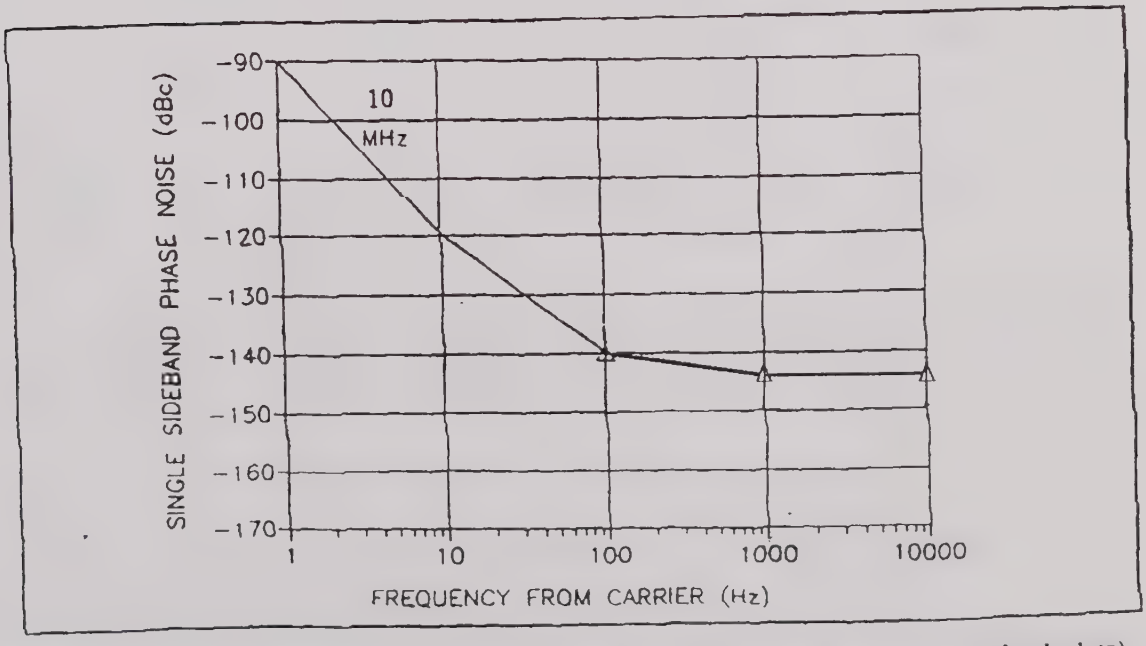


FIGURE 1-3 SINGLE SIDE-BAND PHASE NOISE SPECTRAL DENSITY (1 second time constant, 2nd order loop)

TABLE 1-2 RECOMMENDED TEST EQUIPMENT

ITEM NO. AND DESCRIPTION	REQUIRED CHARACTERISTICS	PURPOSE/USE	EXAMPLES OF APPROPRIATE EQUIPMENT
1. Primary Frequency Standard	Accuracy, stability, and phase noise commensurate with FTS 4040A/RS.	Performance Check	FTS 4060, 4040, 4160, 5030, 4065, 5040 4040A, 4040A/RS
2. Spectrum Analyzer	Freq. range: 100 kHz to 10 MHz Scan Width: 2 kHz to 100 MHz	Performance Check Input Level: 13 dBm/50 Ω	HP 8858B
3. Oscilloscope	Frequency Response: 60 MHz Sensitivity: 10 mV/div Calibrated Sweeps: 2 s to 0.1 us/div	Performance Check Troubleshooting	TEK 2213
4. Digital Multimeter	4 1/2 Digit Display	Troubleshooting Adjustments	Data Precision 2480R
5. Signal Generator	Frequency: 5 Hz to 5 MHz Output: up to 13 dBm/50 ohms	Performance Check Troubleshooting Adjustments	HP 3301A
6. Phase Comparator	Frequency: 10 MHz Linear Output: 0 - 1 V	Performance Check	FTS 6101
7. Strip Chart	Speed: 3cm/h Span: 1, 10 V fs	Performance Check	SOLTEC S4201
8. Power Supply	Power Range: 0 to 40 V 0 to 3 A	Troubleshooting	LAMBDA LA-532
9. Termination Feedthrough	SMA, Male to Female, 50 ohm	Performance Check	TEK 011-0049-01
10. Frequency and Time-Interval Counter	Frequency: 0 to 10 MHz Sensitivity: 100 mV Accuracy: 10 ns, 10 digit display	Performance Check Troubleshooting	HP 5328A

NOTE: If desired, additional test equipment, equipment combinations, and test procedures for frequency-time performance analysis may be obtained in Characterization of Clocks and Oscillators, NIST (formerly NBS) Technical Note 1337, U.S. Government Printing Office, March 1990.

1.4 OPTIONS

1.4.1 Carrying Case (Option 001)

An optional carrying case is available to protect the FTS 4040A/RS during private transportation from site to site. This case provides internal padding to protect the instrument from handling shock. The optional case is not approved for shipping the FTS 4040A/RS by commercial common carriers; see 1.7 below.

1.4.2 1.544 MHz TTL and Balanced DS1 Outputs (Option 063)

The FTS 4040A/RS can be configured with an internal 1.544 MHz synthesizer. This signal displays the same accuracy and frequency stability as the standard FTS 4040A/RS rf outputs. Option 063 cannot be combined with Option 064.

1.4.3 2.048 MHz TTL and Balanced CEPT Outputs (Option 064)

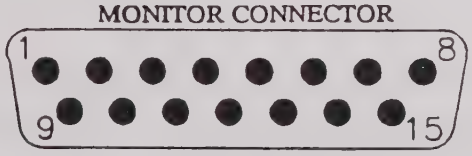
The FTS 4040A/RS can be configured with an internal 2.048 MHz synthesizer. This signal displays the same accuracy and frequency stability as the standard FTS 4040A/RS rf outputs. Option 064 cannot be combined with Option 063.

1.4.4 Extended Life Tube (Option 075)

The FTS 4040A/RS can be configured with an optional extended life cesium beam tube. Contact FTS for details of this option.

1.5 MONITOR PIN-OUT

The FTS 4040A/RS is equipped with a fifteen Pin-D connector which allows the user to access the relay contacts of various alarm conditions (described in Figure 1-4).



J11 Rear Panel

PART NUMBER DAU-15P-FO ITT CANNON
MATING CONNECTOR DA15S

Pin #	J11 User Monitor Connector	Comments
1	Spare	
2	Spare	
3	Spare	
4	Spare	
5	Spare	
6	Fault = CLOSED (DS1/CEPT Alarm)	This set of relay contacts is only available with the DS1/CEPT (Option 063, 064) and indicates improper operation of the DS1 or CEPT output (see Appendix B).
7	Fault = OPEN (DS1/CEPT Alarm)	
8	COMMON (DS1/CEPT Alarm)	
9	Fault = OPEN (Minor Alarm)	A minor fault is generated if the front panel MINOR ALARM LED is illuminated (see Table 2-1).
10	COMMON = (Minor Alarm)	This set of relay contacts is considered a warning of potential problems.
11	Fault = CLOSED (Minor Alarm)	
12	Fault = Open (Major)	A major fault is generated if the front panel MAJOR ALARM LED is illuminated (see Table 2-1)
13	COMMON (Major)	This set of relay contacts indicates the lock or unlocked state of the unit.
14	Fault = Closed (Major)	
15	Spare	

NOTE: The above relay positions are described in their faulted conditions.

FIGURE 1-4 USER MONITOR PIN-OUT

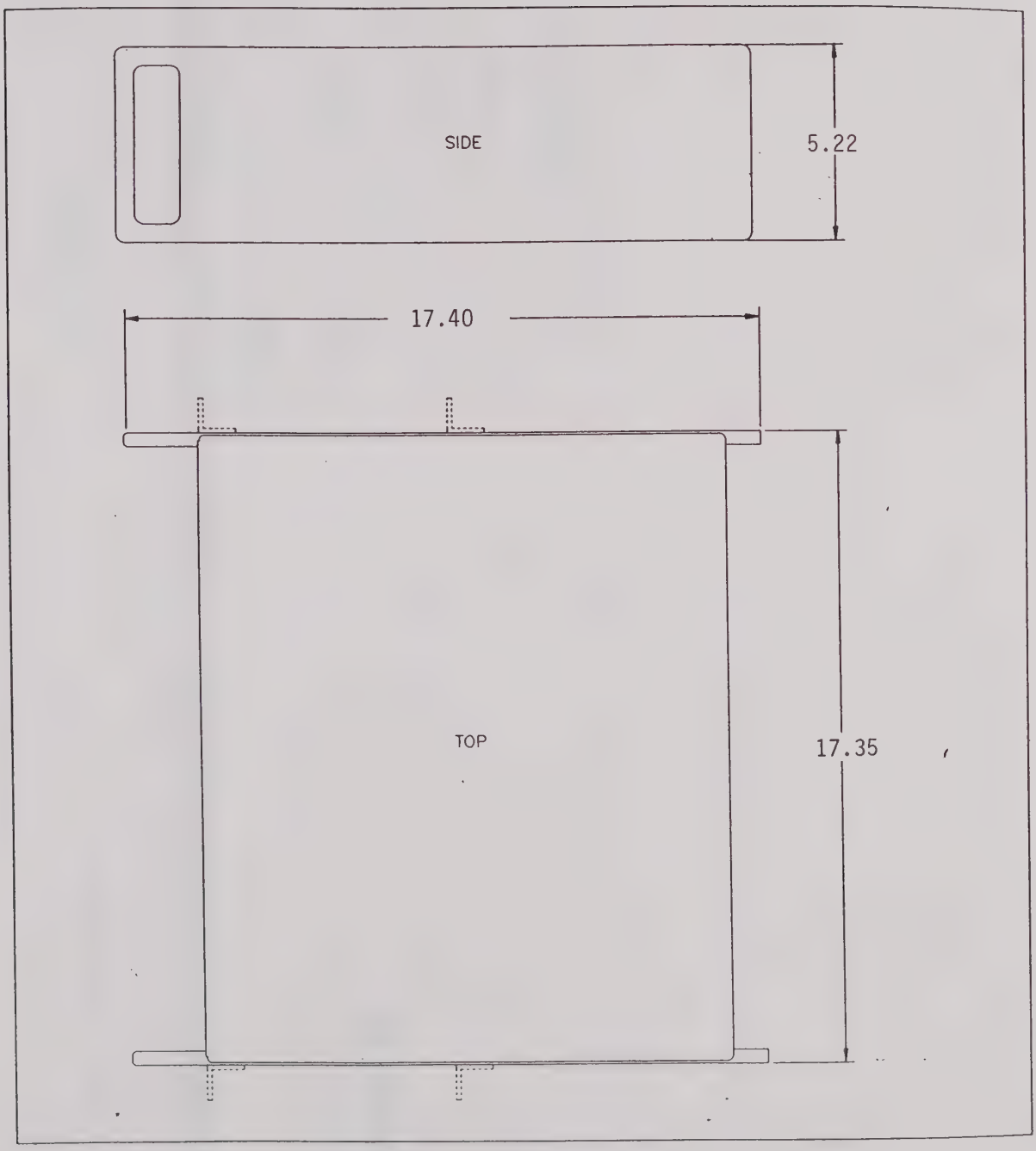


FIGURE 1-5 FTS 4040A/RS (Side Panel and Top View)

FIGURE 1-6 FTS 4040A/RS (Front Panel)

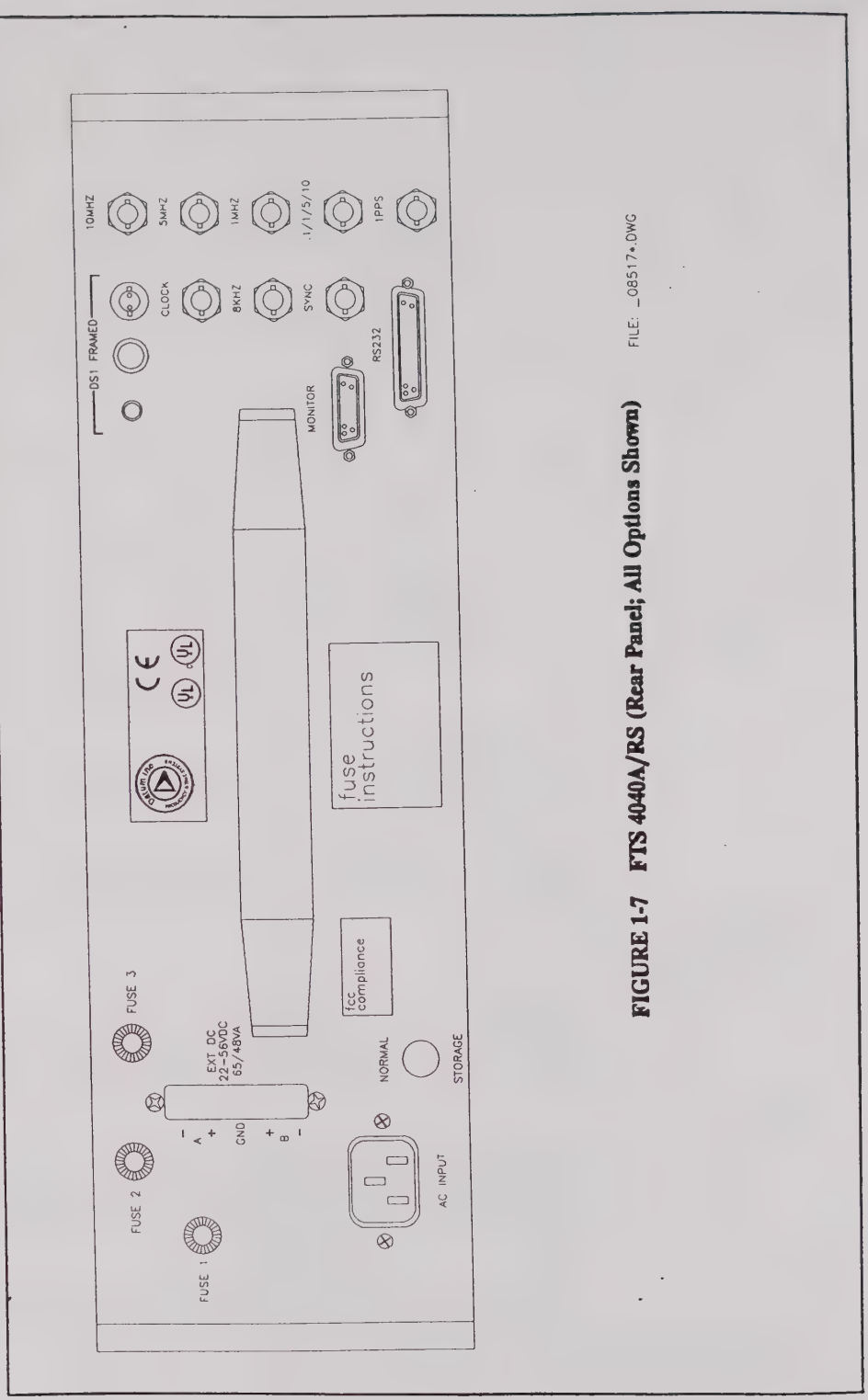


FIGURE 1-7 FTS 4040A/RS (Rear Panel; All Options Shown)

1.6 STORAGE/SHELF LIFE, FTS 4040A/RS

During storage of the FTS 4040A/RS, there are two factors to consider; cesium beam tube vacuum and shelf life.

1.6.1 Cesium Beam Tube Vacuum and Standby Operation

If extended periods of storage is anticipated, the ion pump in the Cesium Beam Tube must be operated to maintain tube vacuum.

The storage mode of operation is highly recommended in these situations. Connect power to the FTS 4040A/RS and switch the rear panel toggle switch such that the STORAGE LED on the front panel is illuminated. In this mode only the ion pump circuitry is functional.

If the unit can't be stored with a permanent source of external power, then periodic storage mode operation cycles must be performed. The minimum period of operation (storage mode) with power is 30 minutes for every six months of storage time. Refer to Section 2 for the turn-on procedure.

1.6.2 Cesium Beam Tube Shelf Life

The operating lifetime of the cesium beam tube is governed by the consumption of cesium as the cesium beam is formed in the beam tube oven. An extended warranty configuration, Option 075, is available.

Extended high temperature storage reduces the expected operating life of the cesium beam tube. The reduction in tube life expectancy for each year at a given temperature may be approximated by Table 1-4.

Table 1-4 CESIUM BEAM TUBE SHELF LIFE

Storage Reduced Life Temperature (°C)	Reduction in Life Expectancy per Year at Storage Temperature
40	20 d
50	1 mo
60	2 mo
70	4 mo

1.7 PREPARATION FOR SHIPMENT

To turn off FTS 4040A/RS prior to shipment, remove ac and ext dc power.

1.7.1 Hazardous Material (HAZMAT) Shipping Considerations

FTS Cesium standards contain a small amount of cesium metal. The cesium isotope used (cesium 133) is non-radioactive. However, because of its reactive chemical properties, cesium is technically classified as a hazardous material by the U.S. Department of Transportation (USDOT) and the International Air Transport Association (IATA). During normal handling the FTS 4040A/RS presents no danger since the cesium is encased within a vacuum sealed metal enclosure. However, hazardous materials, depending upon their specific nature, are subject to certain shipping regulations of the USDOT and the IATA. These regulations govern the shipping case as well as its labeling.

The initial shipment of every FTS cesium standard complies with HAZMAT regulations: the shipping case used has been tested and certified.

FTS has designed this case to meet current hazardous shipping regulations. The case design has been engineered to prevent damage to the unit during shipment.

In order to facilitate customer shipment of its cesium products, Frequency and Time Systems (FTS) provides certified shipping cases which comply with USDOT and IATA regulations. This case provides the necessary physical protection for the instrument during shipping. Contact FTS Technical Service for information about this service.

The cesium standard shipping case is FTS Part Number 08748-701 (vinyl-covered plywood with aluminum-reinforced edges/corners) or PN 4040 (cardboard box).

1.7.2 Packing Materials

The Packing Materials are composed of:

a) an ATA case with protective anti-static foam,

b) labels to identify the shipping case:

Labels:
FRAGILE LABEL
UN LABEL
DANGEROUS WHEN WET
DANGER NO PASSENGER AIRCRAFT
CESIUM UN1407I

1.7.3 Shipping Procedure

The shipper is responsible for the overall condition of the container; i.e., no visible damage to case and to properly place all labels on the case, etc. See Figure 1-4 for an illustration of the shipping container.

1.7.4 Placement Of Labels On Shipping Container

See Figure 1-5 for proper placement of labels.

Make sure an address label, proper HAZMAT labels, and packing slip (if necessary) are affixed to the shipping case and are clearly visible.

1.7.5 Shipment

Several United States and international shipping companies can accommodate properly packaged hazardous materials. United Parcel Service and Federal Express are examples for the United States. Intercontinental (617-569-4400) provides international shipping services.

Contact one of these shipping companies for assistance. If you need additional help, call FTS Shipping Department.

The following information is typically requested:

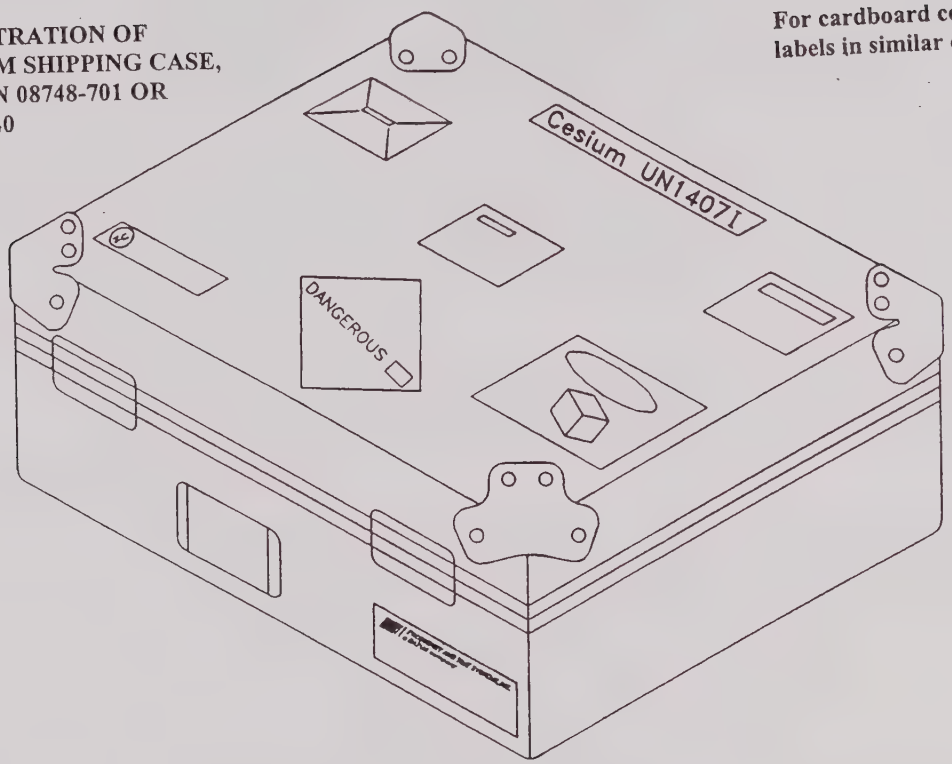
Proper Shipping Name:	Caesium (Cesium) Dangerous When Wet
Class Or Division:	4.3
UN or ID No.:	UN1407I
Quantity & Type Of Packing:	One Fiberboard Box X 5 Grams, or One Plywood Box X5 Grams * Carton(s)
Packing Inst.	412

* Insert number of cartons covered by the shipping paperwork.

FIGURE 1-8

ILLUSTRATION OF
CESIUM SHIPPING CASE,
FTS P/N 08748-701 OR
P/N 4040

For cardboard container, place labels in similar orientation



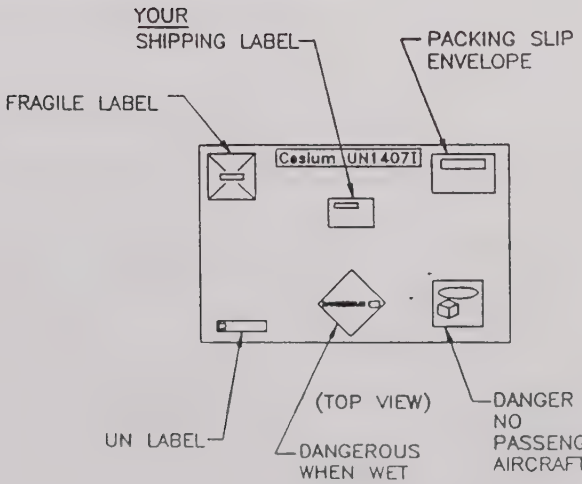


FIGURE 1-9
LABEL INFORMATION

T:\MISC

1.8 INSTALLATION

1.8.1 Environment

When installing the instrument, consideration should be given to standard environmental factors (temperature, humidity, vibration, etc.) and to the presence of magnetic fields that might affect the accuracy of the FTS 4040A/RS. Do not exceed the maximum recommended ambient temperature, 50°C. Do not block the units vents or otherwise restrict airflow when installing unit in rack. Internal temperatures of rack should also be considered for continued safe operation. Avoid installing or using the instrument near large motors, generators, transformers, or other equipment which radiates strong ac or dc fields of 2 gauss or more.

1.8.2 Mounting

The FTS 4040A/RS is designed to be mounted in a standard 19-inch or 23 inch equipment rack. Mechanical loading of rack should be considered so that the rack remains stable and unlikely to tip over. Figure 1-1 INTERFACE CONTROL DRAWING shows applicable dimensions and mounting details. The front panel occupies a height of 5.22 inches. The FTS 4040A/RS is 17.3 inches deep including handles.

The FTS 4040A/RS comes equipped with removable rack mounting brackets. These brackets may be positioned in different configurations to satisfy a variety of mounting requirements. The brackets may be mounted 0 or 3.625 inches behind the FTS 4040A/RS front panel.

1.8.3 Electrical Connections

The FTS 4040A/RS may be powered from an external ac source, 115 or 230 V ac. The instrument may also be powered by an external dc source (22 to 56 V). Before connecting power, check to see that the correct fuses are installed as described on the fuse wiring label:

AC Power: F1 V ~ 90-132 : T2.0A/250 V
V ~ 180-240 : T0.8A/250 V
F3.15 A/250 V

Ext DC: F2, F3 V ⎓ 22-56

For continued protection against risk of fire, replace only with same type and rating fuse. NOTE: The DC fuse is rated at 3.15 A for use in Europe and 3.0 A SB for U.S.

Consideration to the overall loading of the branch circuit should be given before installing any equipment in a rack environment.

Ensure that reliable earthing path is maintained in rack system.

Refer to Figure 1-4 for the location and contact designation for both external ac and dc power connectors.

Connector accessories, for the 063/064 option, the following connectors are available for purchase through Frequency and Time Systems if desired:

Part No.	Description
PJ777	Conn, Bantam Plug
PJ310	Conn, WECO 310
640433-7	Conn, Wire-Wrap Socket Connector

1.8.3.1 External DC Connections

The FTS 4040A/RS employs an internal dc-dc converter to provide a wide input voltage range as well as electrical isolation between the dc input and chassis ground. Either side of the dc input may be at chassis ground potential. The external dc input is protected against reverse polarity connection by a series diode.

SECTION 2

OPERATION

SECTION 2. OPERATION

2.1 INTRODUCTION

This section describes procedures for turn-on, monitoring, alignment and other adjustments of the FTS 4040A/RS Cesium Frequency Standard.

2.2 TURN-ON PROCEDURE

Except for the application of power, no specific user actions are required to turn-on the FTS 4040A/RS and obtain the specified rf output signals. Application of either ac or dc power initiates the warm-up and automatic lock acquisition sequence. Refer to Figure 2-1 for an illustration of the FTS 4040A/RS indicators and controls.

1) Apply ac or dc power to the FTS 4040A/RS.

2) Observe that the INITIALIZATION indicator is illuminated.

3) After approximately 30 minutes, observe that the NORMAL indicator is illuminated.

4) The FTS 4040A/RS has completed its warm-up and lock acquisition process.

Note that DS1 and CEPT balanced outputs (Options 063 and 064) are not present during warm-up until the FTS 4040A/RS achieves frequency lock and the front panel NORMAL indicator is illuminated.

2.3 TURN-OFF AND RESTARTING

To turn off the FTS 4040A/RS, follow the steps below:

1) Remove EXT DC power.

2) Remove ac power.

If power to the FTS 4040A/RS is interrupted, restart the instrument using the turn-on steps above, as applicable. If the instrument is turned off for only a few minutes, frequency lock will be achieved in less than the specified warm-up time.

This figure left blank intentionally.
Refer to Figure 1-6, Section 1 of this manual.

FIGURE 2-1 Intentionally left blank

This figure left blank intentionally.
Refer to Figure 1-7, Section 1 of this manual.

FIGURE 2-2 Intentionally left blank

TABLE 2-1 MONITORS AND INDICATORS

INDICATOR FUNCTION	NOTES
LOCK	Turns on when the frequency control loop is stable.
MINOR ALARM	Turns on to warn that a parameter is outside of preset limits, indicating that adjustment may be required. The preset limits are described in more detail in Appendix A3.2. The FTS 4040A/RS will continue to operate within specification if the NON-FATAL indicator also remains on, there is no damage to the unit during a non-fatal error. Rear panel relay contacts (minor alarm) are toggled in the event of this fault (refer to Figure 2-2).
MAJOR ALARM	Turns on to indicate that a serious error has been occurred. The Cesium beam tube power supply is automatically turned off. Rear panel relay contacts (major alarm) are toggled in the event of this fault (refer to Figure 2-2).
INITIALIZ-ATION	Turns on during the execution of the start-up routine to indicate that WARM-UP is in progress. No error detection during initialization.
EXT DC AVAILABLE	Illuminated when external dc power is connected to the FTS 4040A/RS rear panel. This indicator monitors the output voltage of the internal dc-dc converter.
AC POWER AVAILABLE	Illuminated when AC power is applied to the cesium standard module.
STORAGE	Illuminated when the unit is in the Ion Pump Only mode.

2.4 OPERATIONAL CHECK

After the FTS 4040A/RS has been operating for its specified warm-up time, it can be examined to verify proper operation:

If another reference standard of known accuracy is available, a measurement of the FTS 4040A/RS frequency offset can be made. Use the FTS 6101/001 Phase Comparator and a chart recorder to obtain an 8 hour phase record between the reference standard and the device under test. The frequency difference may be calculated by dividing the phase change (in seconds) by the elapsed time (8 hours = 28800 seconds). For example, an offset of 5×10^{-12} produces a phase change of 144 ns.

2.5 INSTRUMENT MAINTENANCE

NOTE: This section is not applicable to units with S/N's 2000 and up.

2.5.1 Introduction

The adjustments described here are restricted to the long term drift compensation of the cesium tube output signal and to the quartz tube aging compensation.

With this unit, C-field adjustments are not necessary, for the C-field value is servo controlled. The parameters which are important to the unit correct operation are servo controlled and are factory adjusted.

2.5.2 Required Equipment

An IBM PC or compatible with "MONITOR.EXE" remote control software (see Appendix A) or a standard RS-232 terminal.

2.5.3 Oscillator Control Voltage Centering

The oscillator frequency control is done by a digital-to analog converter with a 2 mV resolution in the ± 4 V range.

This voltage is called AR (Ramsey servo) in the software specs. This voltage is added to a 5 V reference voltage in order to apply to the oscillator an input voltage between 1 V and 9 V (Vc).

A MINOR ALARM is detected whenever Vc < 2 V or > 8 V (Alarm No. 8).

If this error is detected, it is necessary to bring the DAC (AR) voltage closer to zero by adjusting the "OSC ADJ" screw (side panel, see Figure 2-3). Before this adjustment, set the loop time constant between 0.1 and 5 sec; to limit phase jumps on the output, it is best to choose the second order mode with a loop tome constant of 1 s.

2.5.4 PreAmplifier Gain Adjustment

The tube output level is measured by the microprocessor in the following way:

With the programmable synthesizer, the microprocessor measures the tube response at various frequencies, in particular at the top of the clock resonance (Ramsey peak) and in the background. The difference between these two values is called Ramsey Peak (RP).

In order to keep the servo loop gain stable and independent of the tube output signal variations, the Ramsey Peak value is numerically normalized around 2500 mV. This normalization is done with the numerical gain (GN) variable.

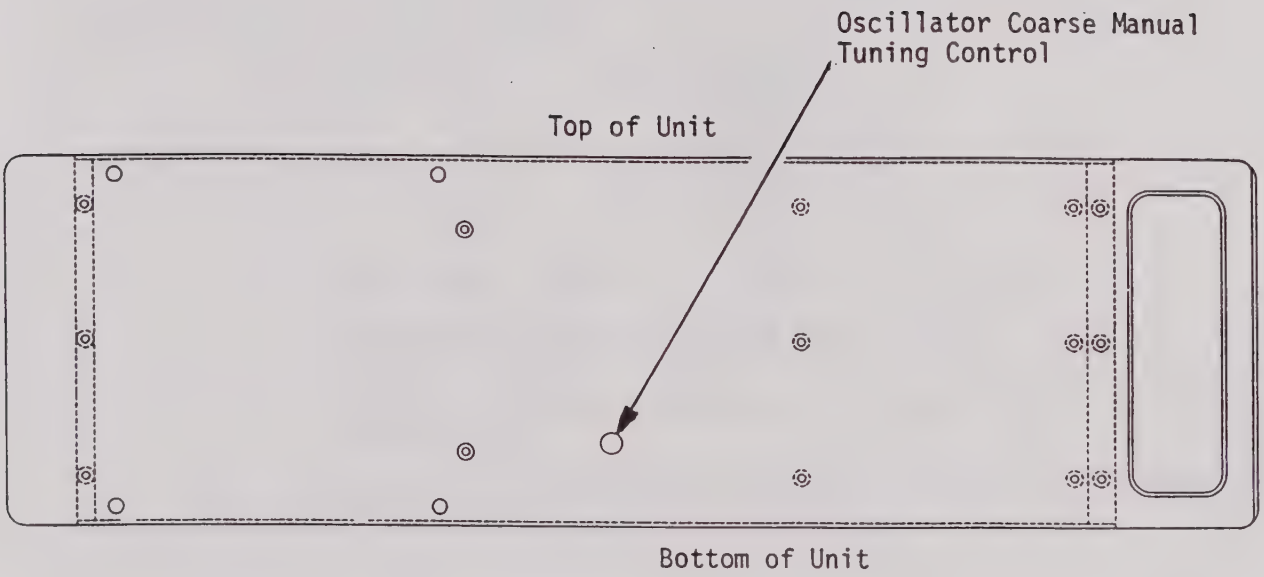


Figure 2-3 Oscillator Adjust Screw

The numerical gain can be varied between 1 and 5. Thus, if the tube signal falls too low, GN reaches the maximum value of 5, then the RP value falls below 2 V and triggers a non-fatal alarm (Alarm #1).

If this happens, it is necessary to raise the preamplifier gain by adjusting the potentiometer (P1) as illustrated in Figure 2-4 clockwise until the numerical gain is equal to 2.

To access potentiometer P1, the bottom cover of the FTS 4040A/RS unit must be removed. A hole in the cover of the FTS 5040 Cesium Module in the location of P1 should be visible.

2.6 CONNECTIONS TO RS 232 INTERFACE

Pin no.	Function
1	chassis (0 V)
2	TXD (data output)
3	RXD (data input)
5, 20	CTS (clear to send)
7	chassis (0 V)
25	+15 V

Data transmission is done by TXD at a standard rate of 300 to 9600 bauds.

When switched on, the unit is in the console mode and supplies at the interface, every second, data about the servo control (see Appendix A).

The transmission speed can be modified when in the console mode and also stored in the non-volatile memory.

The CTS pin is used to pace data transmission; 10 kohm built-in resistor, connected to 15 V, allows the transmission of data even if the CTS is unconnected.

2.6.1 Start-Up Phase

The unit start-up is divided in two periods:

Period I: The microprocessor controlled regulation board and the oven controlled quartz oscillator are switched on.

As long as the quartz oscillator is warming-up, the ionizer filament, the cesium oven and the electron multiplier high voltage are off, in order to keep power consumption low.

Period II: As soon as the oscillator has reached the correct temperature, the cesium oven, the ionizer filament and the EM high voltage are switched on. The cesium oven warm-up time is approximately equal to the quartz oscillator frequency stabilization time after the quartz oscillator warm-up. For this reason, the frequency stabilization time is still approximately 10 minutes and is not affected by the delayed tube turn-on.

The start-up phase ends as soon as one of the following conditions is met:

a) Oscillator warm and stabilized cesium oven.
b) 45 minutes after switching on the unit.

NOTE: If the FTS 4040A/RS has been in storage for an extended period, the warm-up time may be greater than specified.

2.7 TURN-ON PROCEDURE

2.7.1 Turn-On without PC

The 4040A/RS unit turn-on requires no special precaution, since the microprocessor entirely controls the start-up phase.

After switch-on, please check:

- The Front Panel LED state: INITIALIZATION illuminated
- The oscillator 10 MHz (sine) signal output (unlocked).

After the start-up phase (≤45 min), check:

- The Front Panel LED state: LOCK illuminated
- The output frequency: Delta f/f $< 10^{-11}$

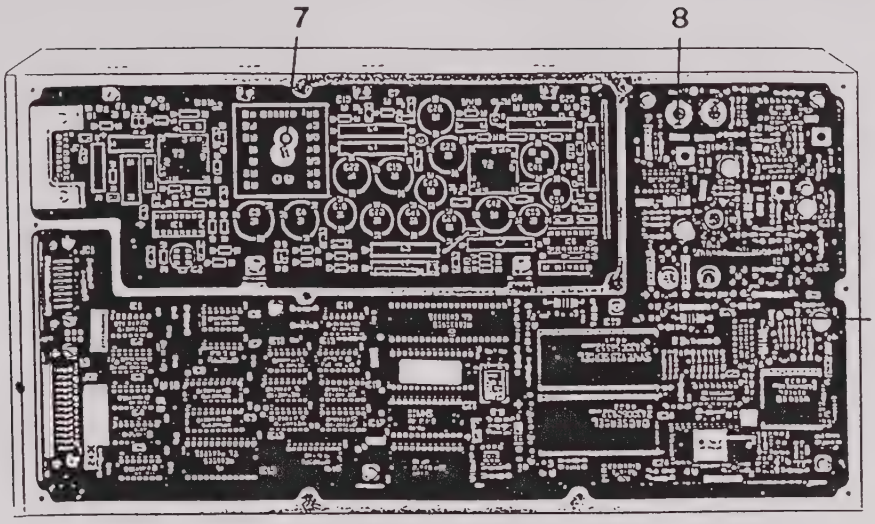
The unit is now ready for operation.

2.7.2 PC-assisted Turn-On

For a more total control, it is best to connect the unit to a PC.

NOTE: The FTS 4040A/RS unit is set for 2400 Baud, 7 data, 2 stop, odd parity.

- Start the MONITOR.EXE program (Appendix A gives a detailed description of the MONITOR.EXE program).
- Press <F8> and enter unit number (5-characters format).



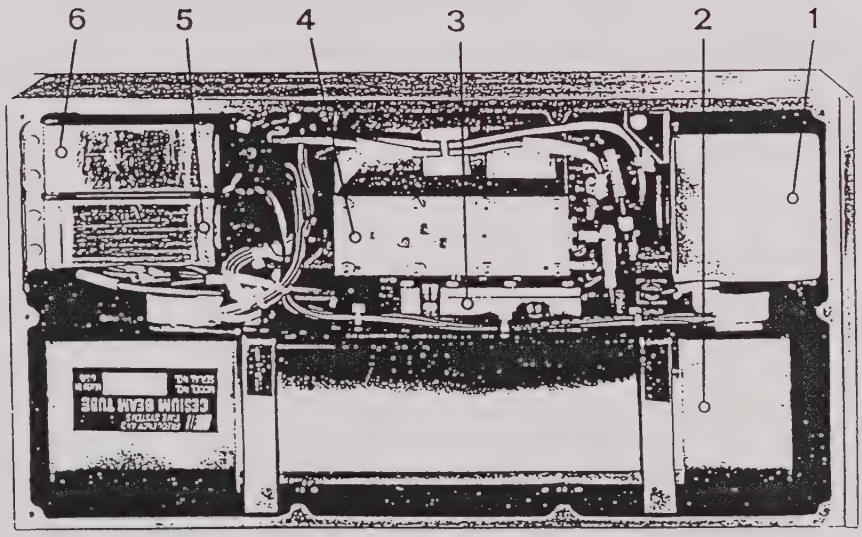


Figure 2-4 Module Layout

1. Quartz oscillator
2. Cesium tube
3. Microwave Adapter
4. 10 MHz ÷ 9,19 GHz Multiplier
5. Ion Pump Power Supply
6. HTEM Power Supply
7. Power Supply Board
8. Servo Control Board

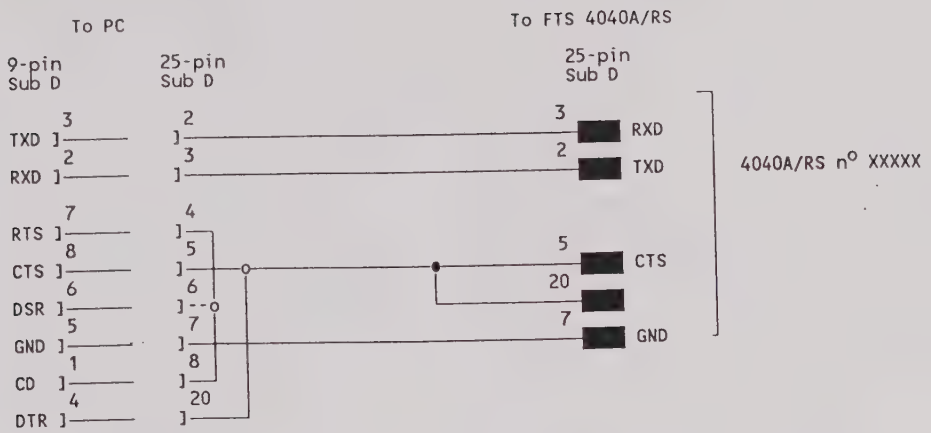


Figure 2-5 Link Between FTS 4040A/RS and PC

SECTION 3

THEORY OF OPERATION

SECTION 3. THEORY OF OPERATION

3.1 INTRODUCTION

The FTS 4040A/RS Cesium Frequency Standard generates sinusoidal signals that are:

o accurate
o spectrally pure
o stable

The accuracy is obtained by comparing the output frequency of a quartz crystal oscillator to the atomic resonance of a beam of cesium atoms. Spectral purity (absence of all frequencies in the output signal except the fundamental frequency) is obtained by using a high performance quartz crystal oscillator to create the desired output signal. Stability (maintaining the specified frequency over a specified time interval) is derived from the invariant resonant frequency of cesium atoms.

The major components of the FTS 4040A/RS are shown in Figure 3.1A. The principle component of the FTS 4040A/RS is the Cesium Frequency Standard Module (CFS). The CFS Module contains all the electronics to generate the required output signals. The two power supplies shown in Figure 3.1A provide redundant/alternate sources of power for the CFS Module.

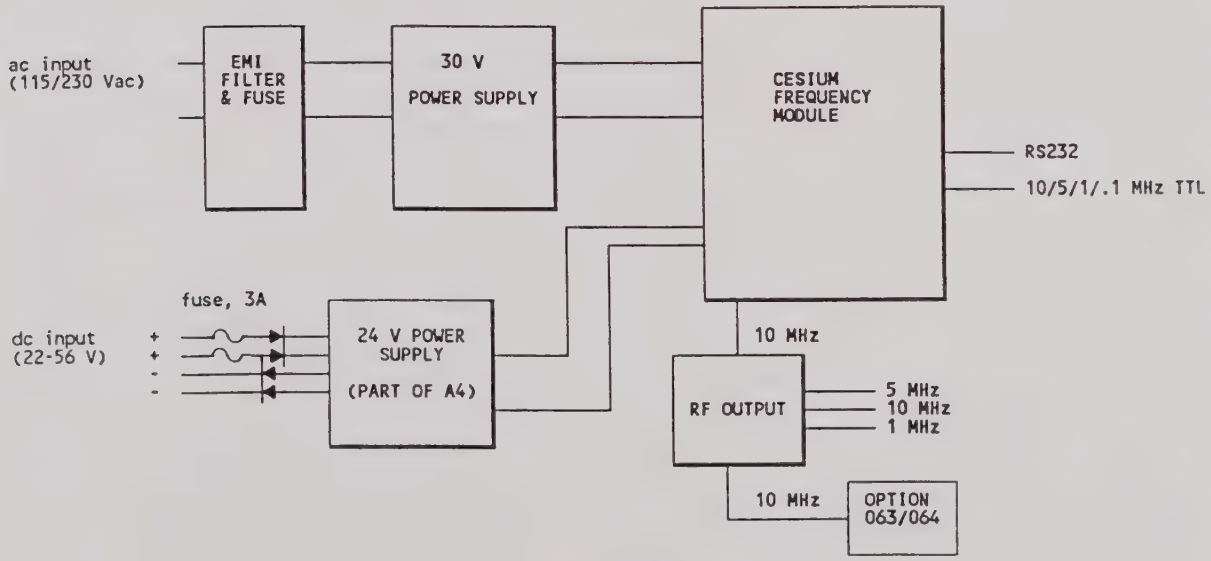


FIGURE 3.1A BLOCK DIAGRAM, FTS 4040A/RS

The theory of operation and a detailed description of the Cesium Module are given in the following sections.

Table 3-1 is a list of the major subassemblies and their respective part numbers.

TABLE 3-1 ASSEMBLIES AND REFERENCE DESIGNATORS

REFERENCE DESIGNATOR	ASSEMBLY NAME	PART NO.
A1	Cesium Frequency Standard Module	08021-501, 502 (Opt 075) 08499-501 (076) 08499-502 (075) 08499-503 (071)
A2	DS1/CEPT Synthesizer	06155-504 (Opt 063) 06155-506 (Opt 064) 08451-502 (Opt 003)
PS1	30 V Power Supply, AC/DC	11393-501
A4	Low Voltage Power Supply	08379-502
A3	RF Output PCB	08383-501

3.2 INTRODUCTION, CESIUM FREQUENCY STANDARD MODULE (CFS)

For years, cesium frequency sources have been constantly improved so as to satisfy the increasingly stringent specifications of time and frequency reference equipment. The availability of easy-to-operate instruments of reduced size and weight and of exceptional accuracy and stability provides the user with great flexibility in the application of cesium standards meeting the stringent requirements of navigation, communication and timing systems.

The cesium frequency module is an atomic frequency standard based on a hyperfine transition in the ground state of the cesium 133 atom. The frequency of this transition defines the international time unit : the second.

3.3 PRINCIPLE OF OPERATION

The CFS consists of (Figure 3.1B).

- A quartz oscillator whose frequency is locked to the hyperfine transition frequency (clock transition) of the cesium atom.
- A cesium atomic beam resonator (cesium tube).
- Control circuits, driven by the quartz oscillator frequency, delivering an interrogation signal. This signal is fed to the atomic resonator. The response of the resonator is a signal whose amplitude is maximum when the interrogation signal frequency is equal to the clock transition frequency.
- Servo loop circuits, fed by the tube output signal, which control the quartz oscillator frequency so that the interrogation frequency is locked to the clock transition.
- Power supplies.

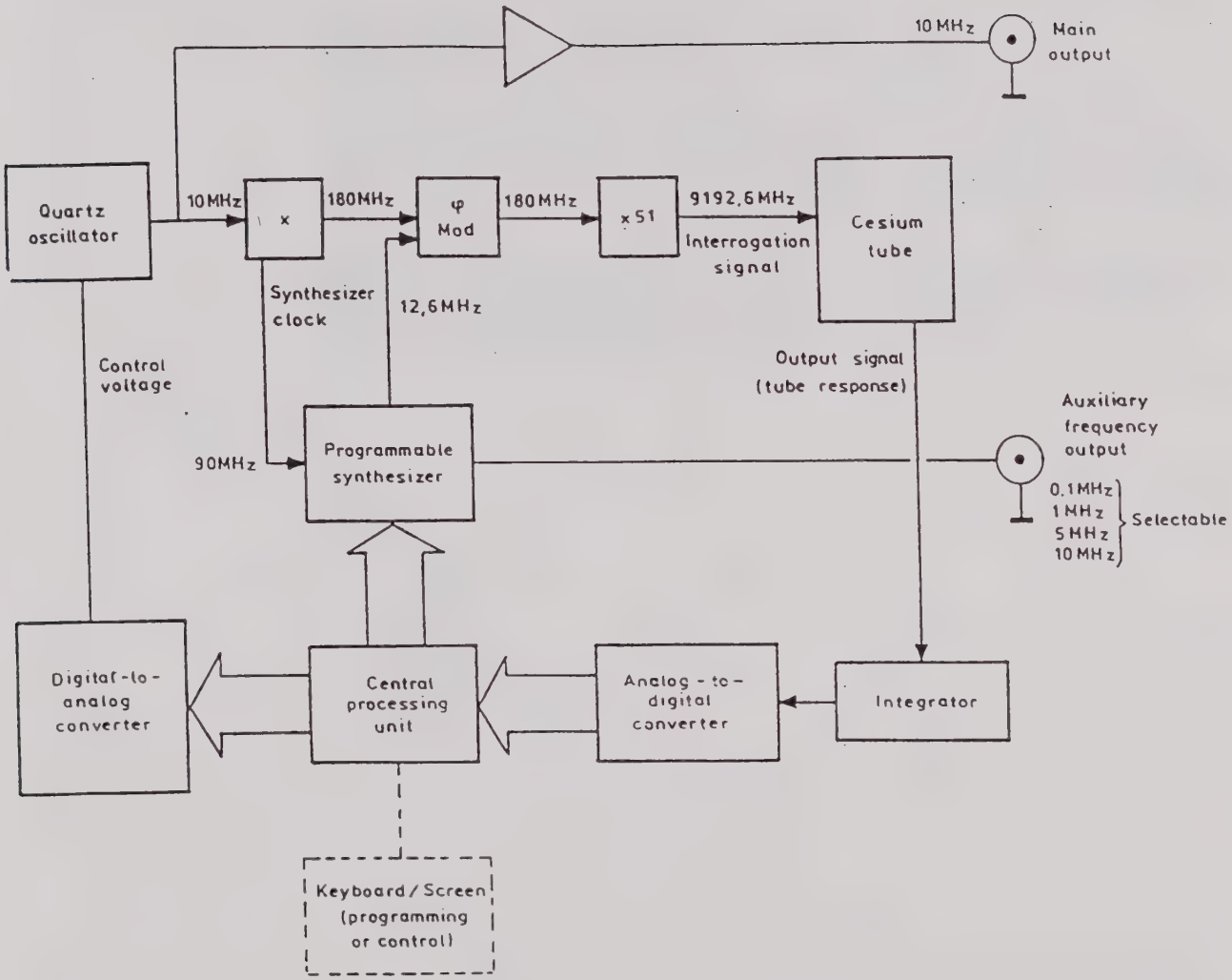


FIGURE 3.1B CFS MODULE BLOCK DIAGRAM

3.3 PRINCIPLE OF OPERATION (CONT'D)

A cesium tube can be thought of as a quadrupole: when the frequency of the input signal scans the atomic transition, the output signal is a microcurrent of variable amplitude; the tube acts as a very narrow band-pass filter coupled to an amplitude detector.

When the frequency f of the microwave interrogation signal scans the clock frequency, the output signal of the cesium tube has the schematic behavior shown in Figure 3.2. A large resonance, called pedestal or Rabi resonance, is topped by interference fringes or Ramsey fringes (Ramsey pattern). The central fringe, or central line, provides the reference to which the interrogation signal frequency and, consequently, the quartz oscillator frequency are locked.

Moreover, the microwave spectrum displays six other resonances of similar structure, symmetrically disposed and regularly spaced about the central resonance; one of these is shown in Figure 3.2. The central frequency of this resonance pattern (Zeeman line) is linearly dependent on the magnetic field inside the cesium tube: by measuring this frequency it is possible to know and to stabilize the magnetic field inside the tube.

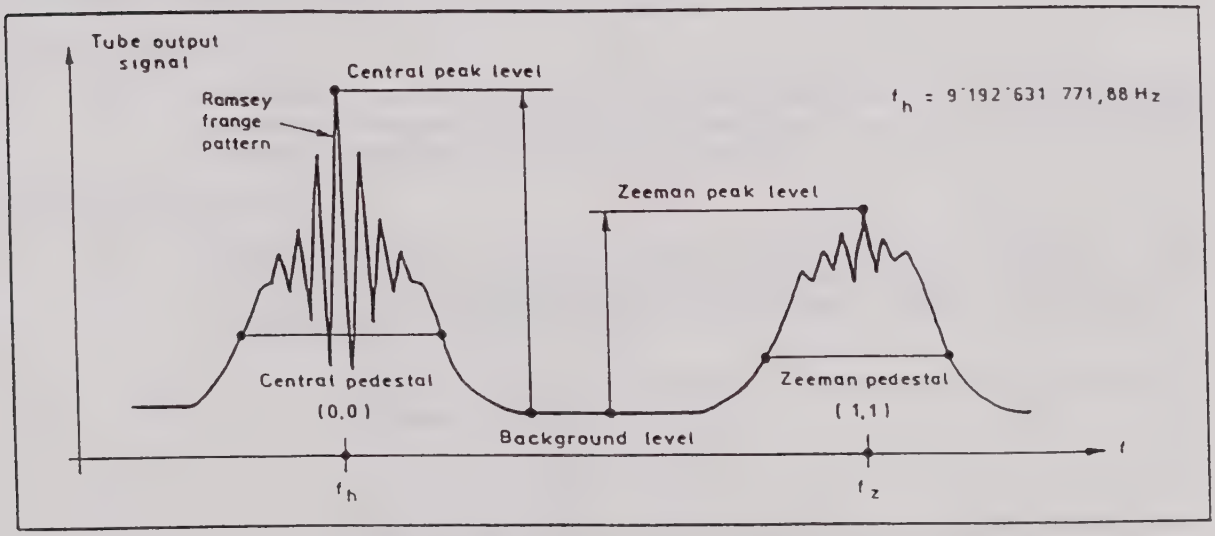


FIGURE 3.2 CESIUM TUBE OUTPUT SIGNAL VERSUS MICROWAVE FREQUENCY

A programmable frequency synthesizer, controlled by a microprocessor and with a short response time, is used to periodically probe several characteristic points of the tube response. This probing is based on two principles:

- 1st PRINCIPLE:

When two frequencies symmetrically disposed about fr (central line) are alternately programmed, the tube output current switches between two levels; their difference is related to the offset of the quartz oscillator frequency from the resonant frequency.

Digitized, this difference is processed by the central unit and then fed back to the quartz oscillator.

• 2nd PRINCIPLE:

As the servo loop time constant is much longer than the measuring cycle time, it is possible to periodically "steal" one measuring cycle which is then used to program other frequencies in order to check the different useful characteristic points of the tube response.

Thus, by using this flexible frequency synthesizing technique and the many possibilities offered by a microprocessor driven system, the time frequency standard performs, permanently and in real time operation, the following functions:

- Check of the central line centering through symmetrical testing of the pedestal.
- Measurement of the central line peak value relative to background.

3.4 DESCRIPTION AND OPERATION

3.4.1 Atomic Resonator

The standard cesium tube operates like a passive resonator. The resonator output signal displays very narrow resonances (Q = 2 E7) when the interrogation signal microwave frequency is close to one of the transition frequencies of the cesium atom.

3.4.1.1 Characteristic Transitions

Fig 3.4.1.1A shows the 16 possible energy levels of the ground state of the cesium atom versus the magnetic field; they are specified by the quantum numbers F,m (F=3 or 4, m=-F -F+1, ..., F-1, F). A microwave magnetic field can induce atomic transitions from one state (3,m) to another (4,m') on the following conditions:

1) The microwave frequency is equal to E/h, where E = the energy difference between the two levels

   h = 6.6 E-34 Js (Planck's constant)

2) m = m' if the microwave magnetic field and the static magnetic field (called C-field) are parallel.

   When the static magnetic field is weak (B <1 E-5 [T]), the corresponding transition frequencies are equidistant and result in the microwave spectrum (tube response) of Figure 3.2.

The resonance frequency changes with the magnetic field according to the following relations:

a) if m = 0, the change is quadratic:

$$f_0 (B) = f_{00} + 427.45 \times 10^8 \ B^2 \ [Hz]$$

where f_{00} = 9,192,631,770 Hz (by definition of the SI second), and B is given in Tesla.

This (3;0 - 4;0) transition is largely insensitive to magnetic field variations and thus is used as a frequency reference in cesium standards. The (3;0-4;0) transition is the "clock transition" and the corresponding frequency is the "clock frequency".

b) if m = 0, the resonance frequency change with the magnetic field is linear:

$$f_m(B) = f_{00} + m\ 7.0084 \times 10^9\ B \quad [Hz]$$

where B is given in Tesla and m = -3; -2; -1; +1; +2; +3.

The linear variation of these 6 transition frequencies is due to the Zeeman effect.

f_1, called the Zeeman frequency is specially interesting since it can be used to measure and, if necessary, to servo lock the magnetic field to a preset constant value.

In a strong magnetic field (B > 1 [T], Figure 3.4.1.2A) the energies of the 3;m and 4;-4) states decrease with the magnetic field B, whereas they increase for the other (4;m) states. This feature is used for state selection, or selective deviation of atoms in a strong and inhomogeneous magnetic field.

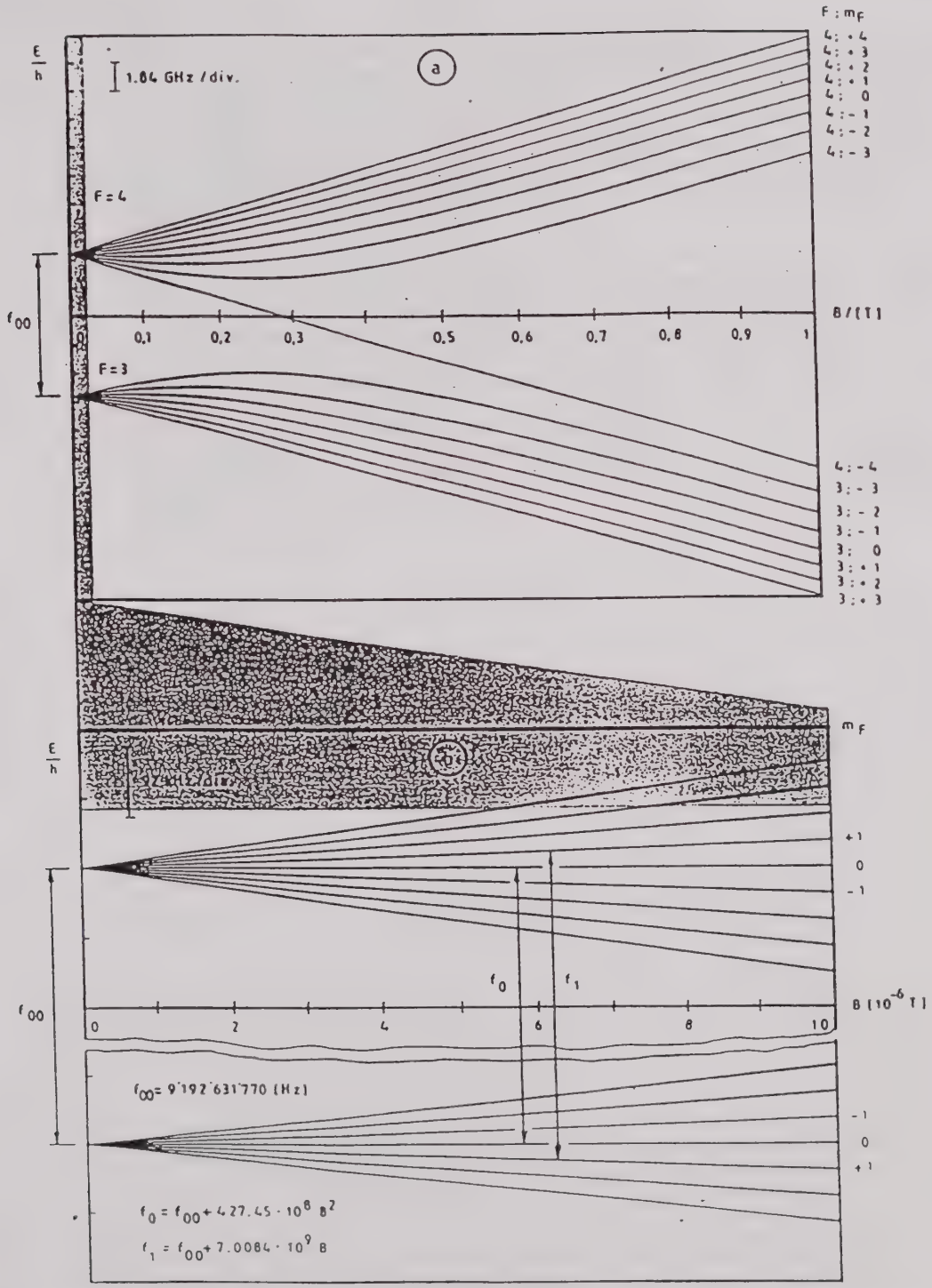


FIGURE 3.4.1.1A ENERGY LEVELS AND MICROWAVE FREQUENCY TRANSITIONS IN THE CESIUM ATOM

3.4.1.2 Resonator Description and Operation

The resonator is set in a metallic vacuum vessel, thoroughly leakproof and in which a ion pump maintains a very high vacuum (Figure 3.4.1.1B). The cesium is placed in a small oven; the heated atoms evaporate through an opening appropriately shaped to produce an atomic beam parallel to the tube length. When they leave the oven, the atoms are equally distributed in each of the 16 energy levels; they then undergo a selective deflection by the strong inhomogeneous magnetic field inside the A magnet gap (first state selector). Atoms in the (3;m) and (4;-4) states, with lower energy in strong magnetic field, are deflected towards strong field regions whereas the other atoms move in the other direction.

The (3;m) and (4;-4) atoms selected by the A magnet enter, through two successive magnetic shields, a region of weak and very homogeneous magnetic field (C-field; $B = 6\ \mu T$). The u-shaped microwave cavity (Ramsey cavity) is placed in this region in such a way as to twice intercept the atomic beam path; when the atomic beam enters the cavity, the atoms are subjected to a microwave field at frequency f_0 which induces transition from (F=3;m=0) to (4;0) state and are then deflected by the second state selector (B magnet) towards the detector.

The detector is a metal filament electrically heated at high temperature; the impinging atoms are re-emitted as ions that are then accelerated by an electric field and deflected by a mass spectrometer towards the first dynode of an electron multiplier. The electron multiplier output is a current proportional to the atomic flux on the detector; this current is the output signal of the cesium tube.

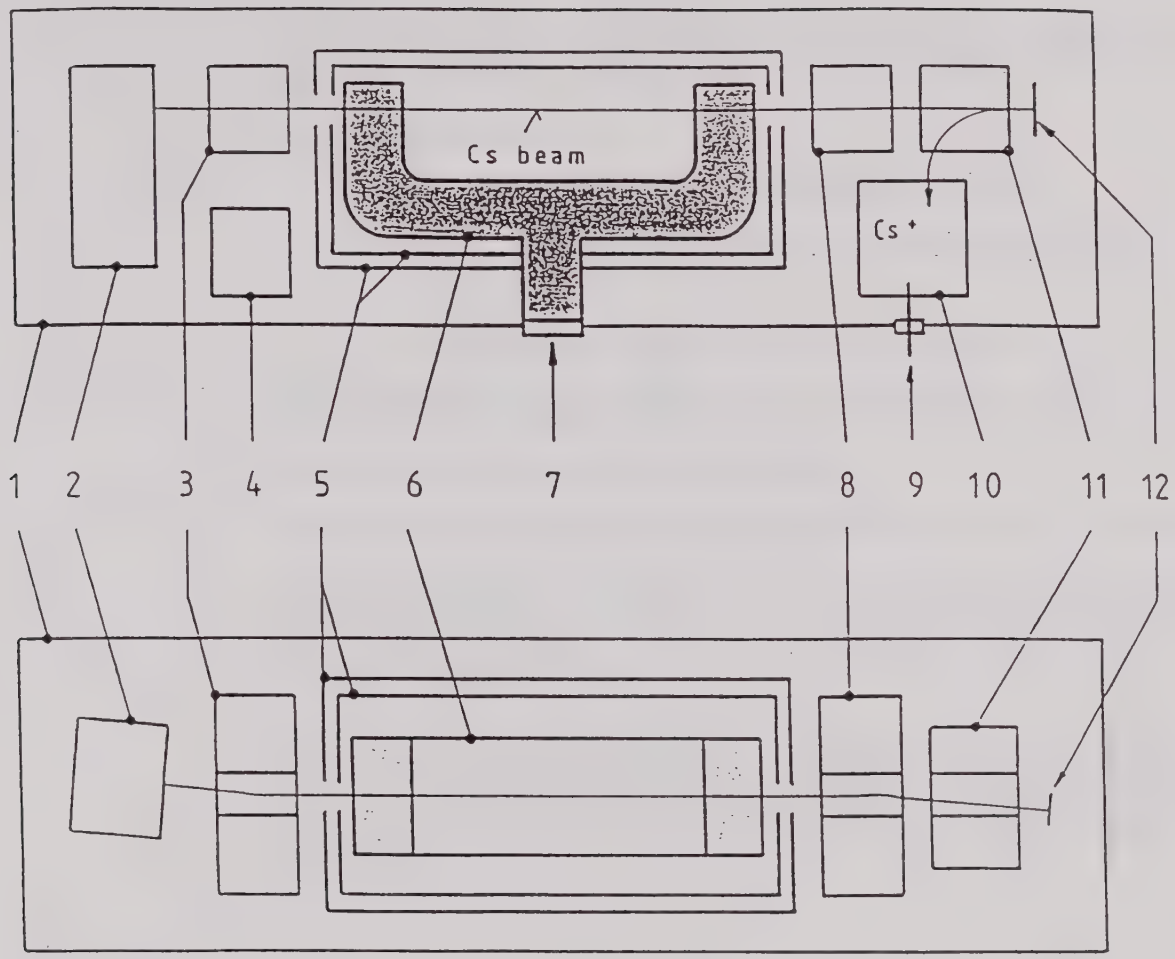


FIGURE 3.4.1.1B SCHEMATIC CROSS SECTION OF THE CESIUM TUBE

1. Vacuum envelope
2. Cesium source
3. A magnet
4. Ion Pump
5. Magnetic shields
6. Microwave cavity (Ramsey cavity)
7. Microwave interrogation signal input
8. B magnet
9. Error signal output
10. Electron multiplier
11. Mass filter
12. Ionizer filament

3.5 CONTROL CIRCUITS DESCRIPTION

The control circuit's main function is to generate, starting from the quartz oscillator, an interrogation signal fr with a frequency close to the hyperfine transition frequency (f_0) of cesium.

These circuits also supply:

- Test signals to monitor different points of the tube response.
- Signals with fixed frequencies between 100 kHz and 10 MHz (auxiliary output signal).
- An interrupt signal IT (of 17.92 ms period) for the central unit.

The interrogation and the test signals result from the addition of a programmable signal of frequency F1/N to other signals derived from the quartz oscillator.

(F1 = 90 MHz and N is programmable from 486 to 710).

The interrogation signal of frequency fr results from the following operations (see Figure 3.5)

For N = 683, F1/N is equal to 131 771.6 Hz. This frequency F1/N is added to 12.5 MHz to obtain 12 631 771.6 Hz. This signal modulates the phase of the 180 MHz signal, thereby supplying, through multiplication by 51, the atomic transition frequency 9 192 631 771.6 Hz. To obtain the ± 193 Hz excursion needed to servo control the oscillator, N is alternately programmed equal to 682 and 684.

Control circuits are mainly composed of a circuit performing frequency multiplication and addition, a circuit performing multiplication by 51 and a programmable frequency synthesizer including a fine frequency vernier. The first stage provides a 9-fold multiplication of the oscillator frequency (10 MHz). This 90 MHz signal is applied to the multiplication and addition chain generating the tube interrogation signal and to the clock input of the frequency synthesizer (HC1 circuit).

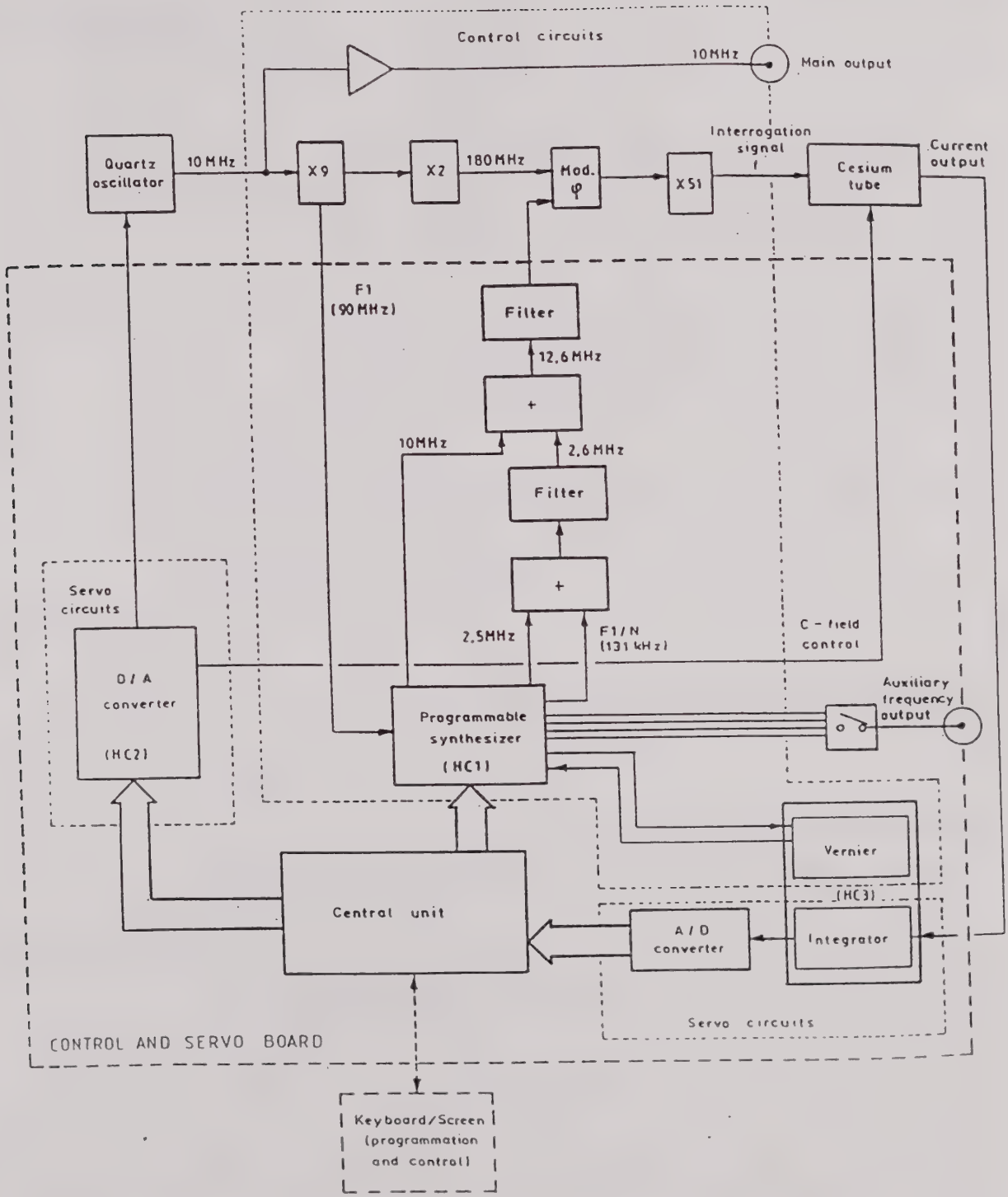


FIGURE 3.5 GENERAL BLOCK DIAGRAM: CONTROL AND SERVO CIRCUITS

3.5.1 Programmable Synthesizer

In the HC1 synthesizer, the 90 MHz signal is applied to:

- A frequency divider chain delivering:
  - 10 MHz, 5 MHz, 1 MHz and 0.1 MHz signals which are selected by a multiplexer (IC26). This is the frequency standard auxiliary output.
  - An interrupt signal (IT 17.92 ms) for the central unit, defining the length of the elementary measuring cycle.
- A programmable frequency divider chain delivering the F1/N signal mentioned above. Various dividing factors are programmed by the central unit in order to explore the central peak and other characteristic points of the Ramsey pattern (Clock peak, Zeeman peak, pedestal, background).

Fine Frequency Vernier

The hybrid circuit HC3 operates as a vernier to provide a fine frequency shift of the 131 kHz signal supplied by the synthesizer (HC3 also includes an integrator of the tube signal).

The vernier can be used for synchronization of the clock output signal and for its synchronization for a limited time interval.

3.6 SERVO LOOP DESCRIPTION (SEE FIGURE 3.6)

3.6.1 Amplifier - Integrator

The tube output signal is fed to a preamplifier (IC27) then to an integrator in the hybrid circuit HC3.

The integrator has a DC level compensation circuit controlled by a voltage delivered by the D/A converter HC2.

The amplification is ten times higher during servo clock control periods than during test periods.

The integrator temporarily latches the output voltage while it is digitized by IC24, before starting on the next acquisition cycle.

3.6.2 Analog-to-Digital Converter

The output voltage from the HC3 integrator is converted by the A/D Converter IC24 to a binary number which is read then processed by the central unit to determine the correction to be applied to the quartz oscillator.

The A/D converter IC24 also digitizes other voltages, which are delivered by the IC25 multiplexer.

3.6.3 Quartz Oscillator Frequency Control

The quartz oscillator frequency is controlled by means of the output voltage from the servo loop (1st order or 2nd order loop, the latter allowing the use of large time constants without introducing phase error due to medium term instability of the oscillator).

The 12 bit value of the control voltage is supplied by the central unit to a high resolution D/A converter (hybrid circuit HC2). The minimum resolution on the control voltage from this DAC circuit is 2 μV, which allows correction of the oscillator frequency in 1 E-13 steps.

3.6.4 Central Unit

The central unit uses a 68B09 microprocessor.

The interrupt signals NMI, IRQ and SWI are used. The 1.2288 MHz microprocessor clock is driven by a 4.9152 MHz quartz, as is also a 2.4576 MHz clock used by the baud rate generator IC4.

The IC23 circuit supplies a 10 ms RESTART pulse at turn-on and when the 5.12 V power supply voltage drops by 5% or more.

The memory is composed of:

- A 32 kbytes program memory (IC20).
- A 2 kbytes static RAM (IC21).
- A 2 kbytes EEPROM memory (IC22). Writing in this memory is protected while in the RESTART phase and afterward by a software lock.

The memory space allocation is shown in Figure 3.6.4.

The various sub-modules addresses are decoded by the IC16, IC17 and IC12 circuits.

The input/output lines of the RS232C serial link are controlled by the IC10 (ACIA).

The programmable transmission speed is fixed by the IC circuit: the speed can be auto-adjusted to that of the connected peripheral or temporarily fixed.

A WATCH DOG system, supplied by the IC7 counter, controls the correct program operation. Using the 2^7 (pin 8) output of the IC7 counter, the WATCH DOG circuit automatically supplies a RESTART pulse if it is not re-initialized at least every 10 seconds (IC7, CLEAR pin). In order to detect the software problems with a 100% probability, two initializing pulses are simultaneously sent to the WATCHDOG circuit; the circuit then checks that these two pulses are indeed simultaneous: in fact, the first one opens a gate allowing the validation of the second one (input 1 and 2 of IC6).

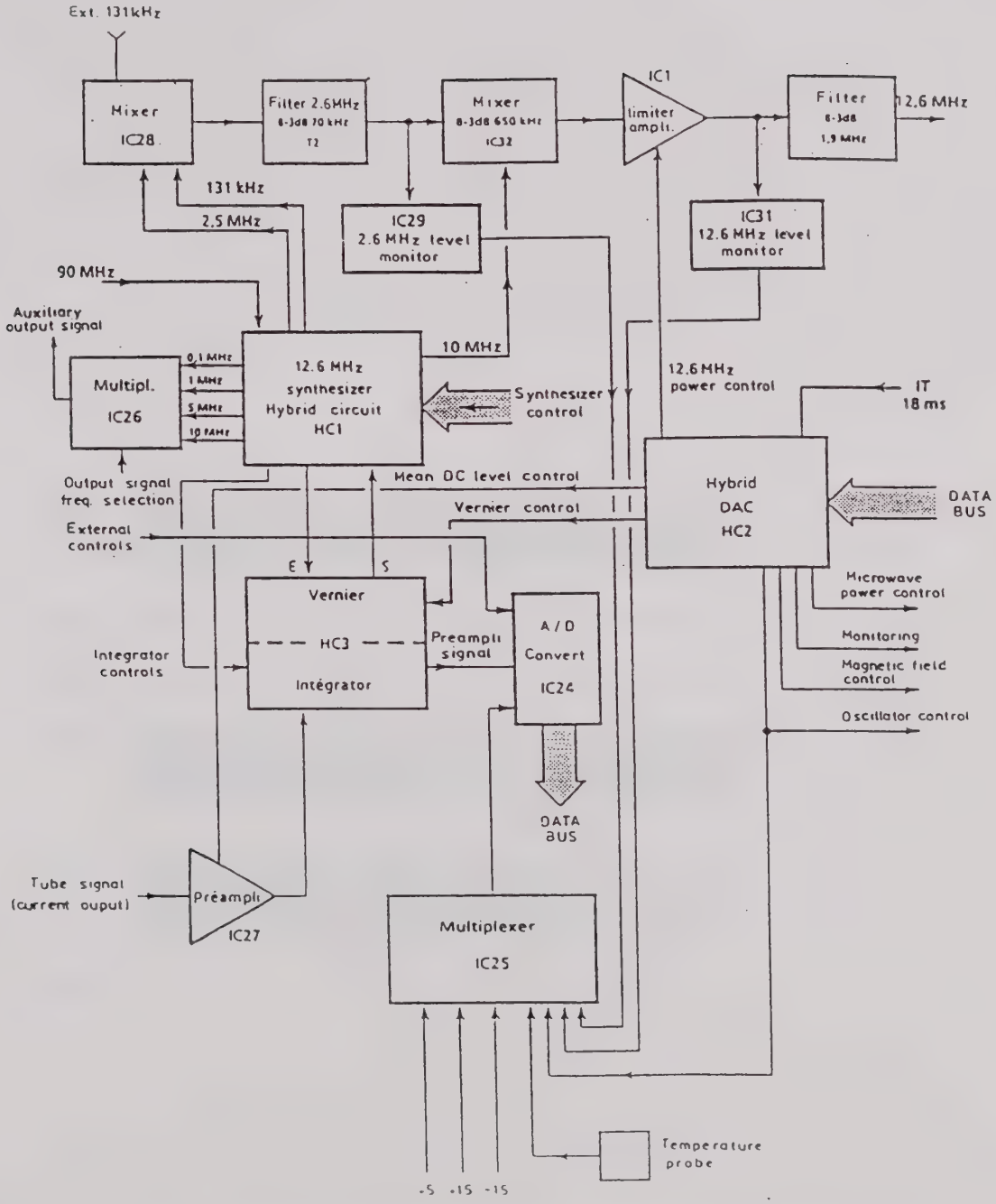


FIGURE 3.6 BLOCK DIAGRAM: SERVO AND CONTROLS (ANALOG CIRCUITS)

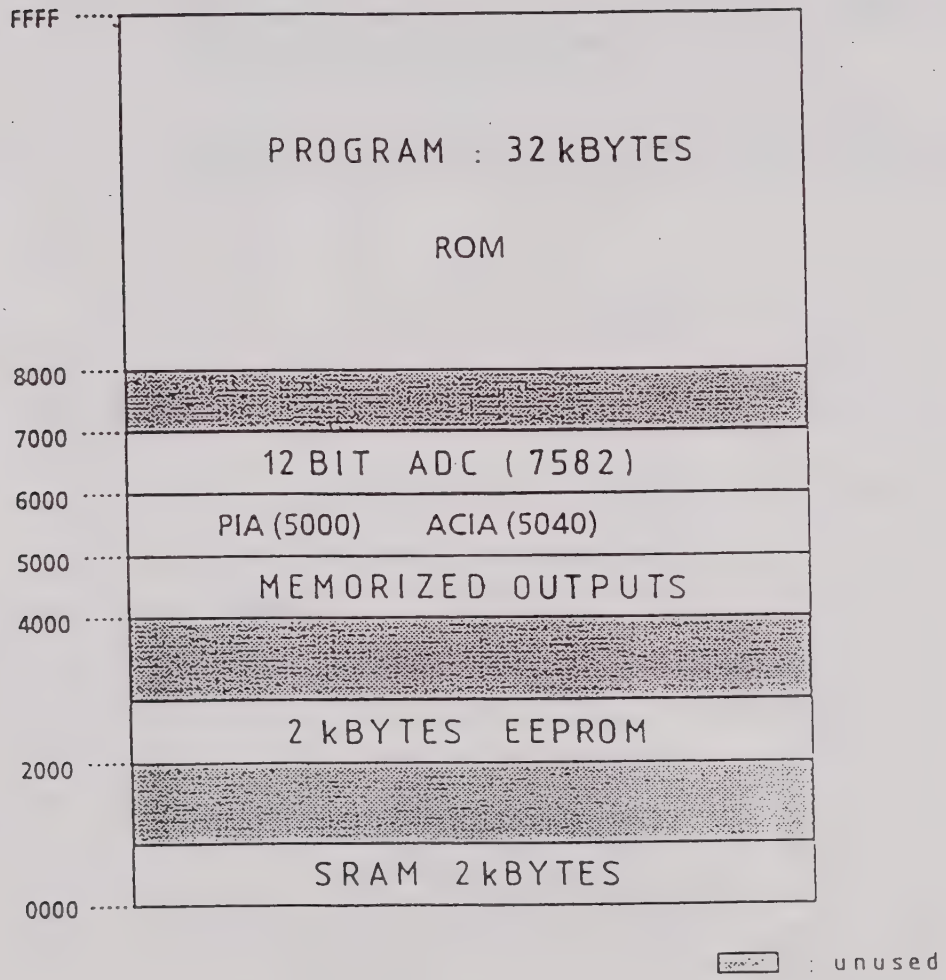


FIGURE 3.6.4 MEMORY SPACE ALLOCATION

3.7 CONTROL AND SERVO CIRCUITS OPERATION

3.7.1 Measurement Sequences

The clock operation (Figures 3.7.1A and 3.7.1B) is divided into elementary periods of 17.92 ms by the IT interrupt signal coming from the frequency synthesizer.

At the beginning of each elementary period, the interrogation frequency changes and so does the tube output signal. After a 2 ms dead time (to eliminate transients), the signal is averaged over 16 ms by analog integration; it is then latched and processed by the microprocessor depending on the interrogation frequency (servo loop, test, etc).

The clock operation is composed of an initial phase (para. 3.7.2) followed by the phase of normal operation (para. 3.7.3). During the normal operation phase, the clock frequency servo is periodically interrupted for elementary periods of testing described later (para. 3.7.4).

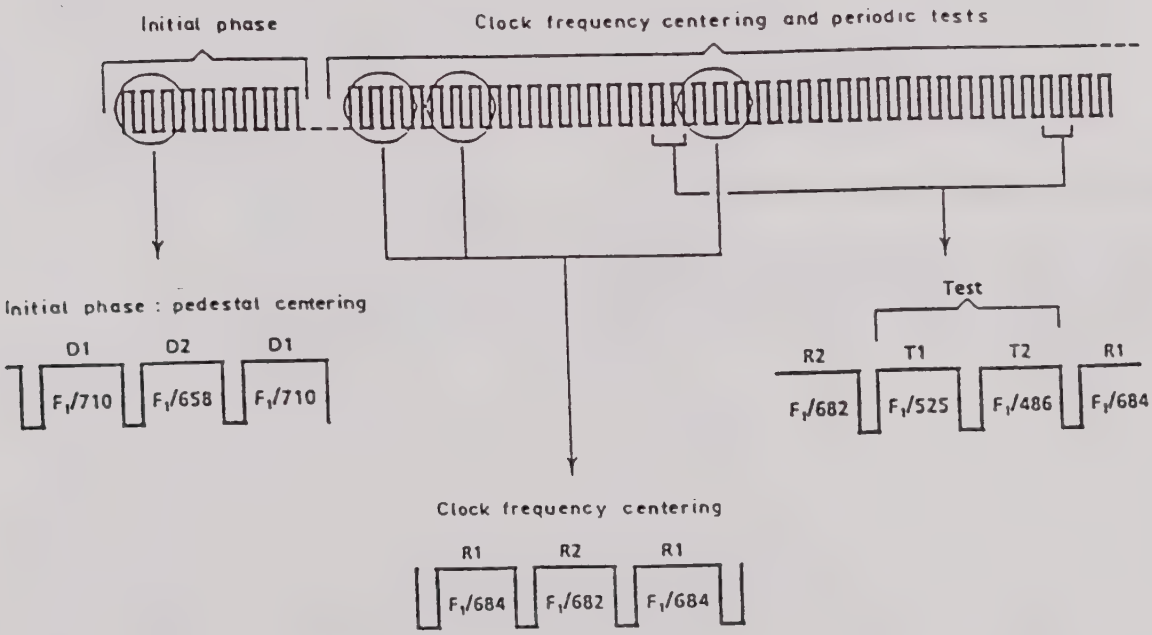


FIGURE 3.7.1A RESONATOR INTERROGATION SEQUENCES

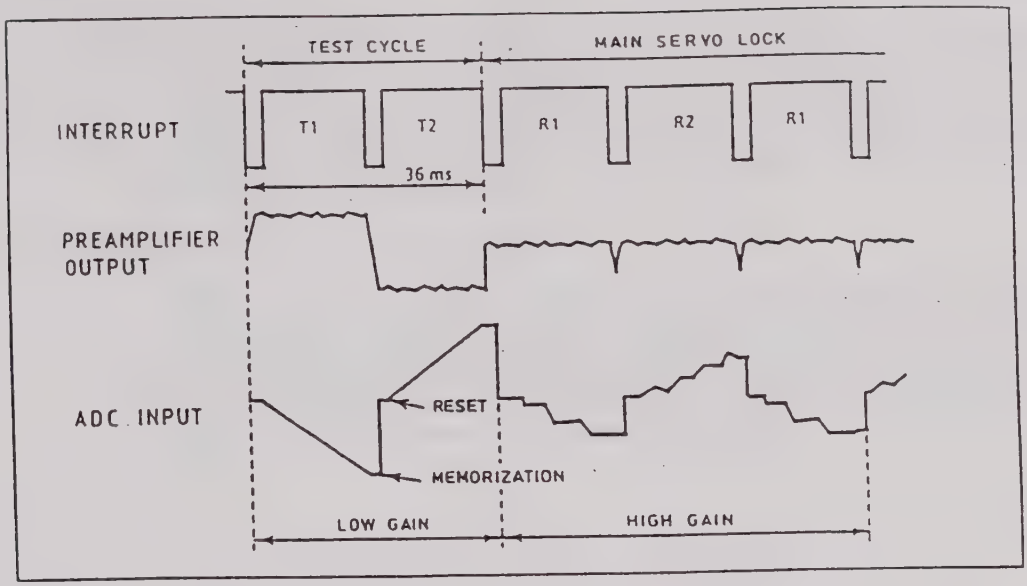


FIGURE 3.7.1B ANALOG PROCESSING SEQUENCE

3.7.2 Initial phase (see Figure 3.7.2)

While in the initial phase, the servo loop control centers the quartz oscillator frequency on the clock resonance pedestal.

To that end, the control circuits apply to the tube input, periodically, the and for successive periods of 17.92 ms (D1 and D2 in Figure 3.7.1A), two signals of frequencies fr_{10} and fr_{11} equal to fr ± 5 kHz. These frequencies fr_{10} and fr_{11} are symmetrical about fr, clock central peak frequency.

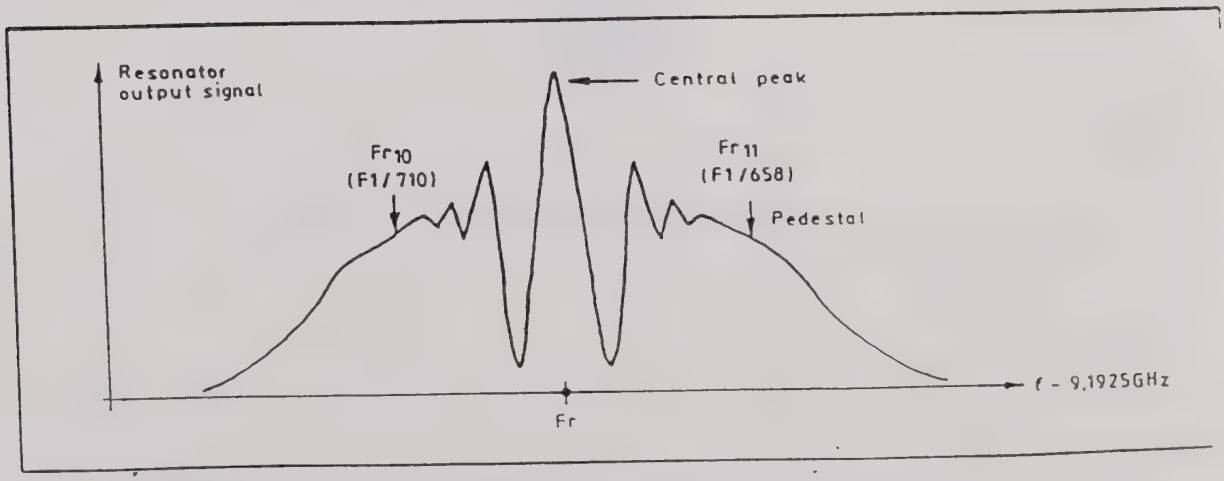


FIGURE 3.7.2 CLOCK RESONANCE: LOCKING TO THE PEDESTAL

The control circuits supply fr_{10} and fr_{11} by alternately programming, on the frequency synthesizer output, frequencies F1/N equal to F1/710 and F1/658, i.e. 126 760 Hz and 136 778 Hz (Fr ± 5kHz). As the pedestal wings are symmetrical about the central line, the signal levels associated with fr_{10} and fr_{11} are equal when their mean frequency is centered on the pedestal. Any difference between these levels induces a correction of the oscillator frequency. The initial phase, resulting in the centering of fr_{10} and fr_{11} on the pedestal, goes on until the centering error is smaller than approximately 500 Hz.

3.7.3 Central Peak Frequency Lock (Figures 3.7.3A & 3.7.3B)

The quartz oscillator frequency is locked to the clock resonance central peak frequency in the following way: the control circuits apply to the tube input two signals fr_{20} and fr_{21}, alternately and for successive periods of 17.92 ms (R1 and R2 in Figure 3.8.1b). The frequencies fr_{20} and fr_{21} are supplied by the control circuits by programming, on the frequency synthesizer output, two frequencies F1/N equal to F1/684 and F1/682, i.e. 131 579 Hz and 131 965 Hz. These frequencies are nearly centered on the Ramsey central peak fo.

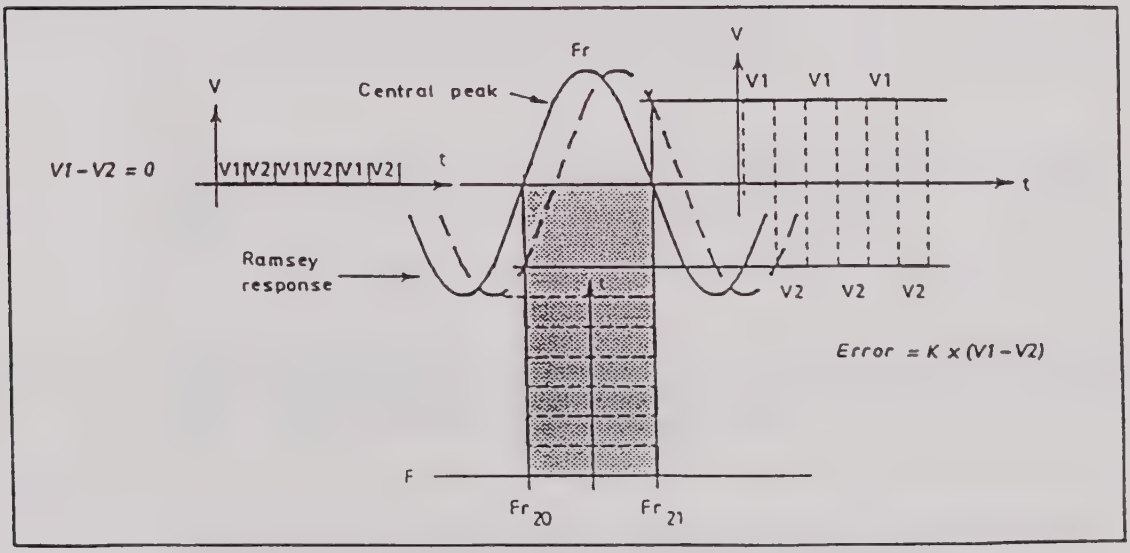


FIGURE 3.7.3A ERROR SIGNAL GENERATION

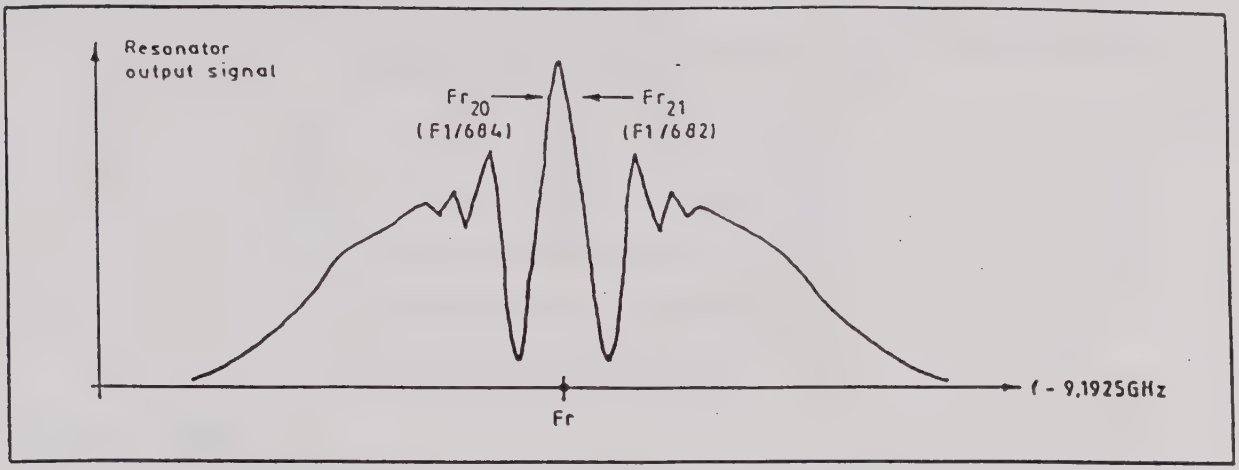


FIGURE 3.7.3B LOCKING TO CENTRAL PEAK

The central peak wings are symmetrical about the clock central peak fo, so if the frequencies fr_{20} and fr_{21} are not exactly symmetrical about fo, the tube output signal levels V1 and V2 (Figure 3.7.3A) differ by an amount V, proportional to the centering error:

$f = 1/2 (fr_{20} + fr_{21})$-fo. This difference is then used to lock the oscillator so that f = 0.

The oscillator servo loop operates either as a first order loop with a time constant adjustable from 0.1 to 10 seconds or as a second order loop with a time constant from 0.5 to 100 seconds. This second order loop cancels the phase error due to a thermal or mechanical shock or to a gravity change, especially when long time constants are used.

3.7.4 Test Cycle

As previously mentioned, two successive 17.92 ms periods (T1, T2 in Figure 3.7.1B) are periodically "stolen" from the normal servo operation for testing purposes.

This test sequence occurs once in 18 periods, i.e. in 322.56 ms, and lasts two 17.92 ms periods (T1 and T2). The introduction of this test sequence is made possible by the large value of the oscillator loop time constant with respect to the length of two successive measuring cycles.

During these periods T1, T2, the central unit can alternately program 11 distinct frequencies F1/N in order to:

a) Servo control the difference between Zeeman and clock frequency (Zeeman frequency lock = C-field servo).

b) Monitor central peak-to-background value.

c) Monitor the Zeeman peak-to-background value.

d) Check the central peak symmetry.

e) Check the clock resonance pedestal symmetry.

f) Servo control the microwave power.

3.7.5 Zeeman Frequency Lock

Zeeman frequency lock is used to maintain the C-field value constant by regulating the current in the C-field coil so that the Zeeman-to-clock frequency difference is equal to a set value. It is thus possible to reduce the influence on the frequency of magnetic perturbation (variations in the shield magnetization due, for instance, to the ambient magnetic field or to temperature changes). This servo lock can be turned off at the user's will.

This Zeeman frequency lock is performed in a manner similar to the central peak lock, with a pedestal centering initial phase followed by a Zeeman peak lock.

In the initial phase resulting in pedestal centering (Figure 3.7.5) two test frequencies fz_{10} and fz_{11} equal to fz ± 7 kHz are applied to the tube input, alternately and for two successive periods T1 and T2. These frequencies fz_{10} and fz_{11} are delivered by the control circuits by programming on the frequency synthesizer, frequencies F1/N equal to F1/525 and F1/486 i.e. 171429 Hz and 185185 Hz.

In the Zeeman peak frequency lock, two other frequencies, fz_{20} and fz_{21}, are applied to the tube input for two other successive periods T1 and T2. These frequencies are nearly centered on the Zeeman frequency fz and are approximately equal to fz ± 350 Hz. They are delivered by the control circuit by programming F1/N equal to F1/506 and F1/504, i.e. 177 866 Hz and 178 571 Hz.

The associated output signals are processed as in para. 3.7.3; the feedback signal is used to adjust the C-field current.

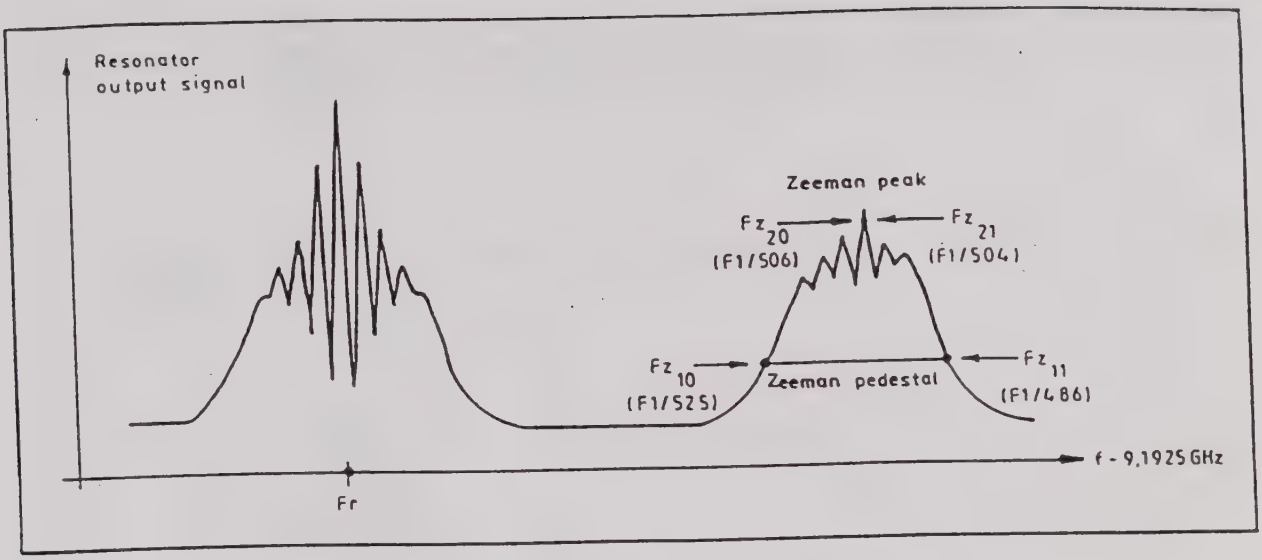


FIGURE 3.7.5 LOCKING TO ZEEMAN PEDESTAL

3.7.6 Signal-to-Background Monitoring (Central Peak)

This monitoring (Figure 3.7.7) is done during T1, T2 test periods, for instance every 3225 ms, by alternately applying to the tube input first a signal with frequency fr, centered on Ramsey central peak, then a signal with frequency fb, (background signal) centered halfway between the clock and the Zeeman resonance. These frequencies are delivered by the control circuits by alternately programming on the frequency synthesizer, frequencies F1/N equal to F1/683 and F1/580, i.e.131 772 Hz and 155 172 Hz.

The difference between the associated tube output signals directly measures the central peak-to-background level. This level is then regulated by correcting the input gain of the feedback loop. Thus, in spite of tube aging, loop gains and alarm levels can be kept constant.

3.7.7 Signal-to-Background Monitoring (Zeeman peak)

This monitoring (Figure 3.7.7) is done during T1 and T2 test periods by applying, to the tube input, signals with frequency fz (centered on Zeeman central peak) and with frequency fb (background signal). Frequencies fz and fb are supplied by the control circuit by programming F1/N equal to F1/505 and F1/580, i.e. 178 218 Hz and 155 172 Hz.

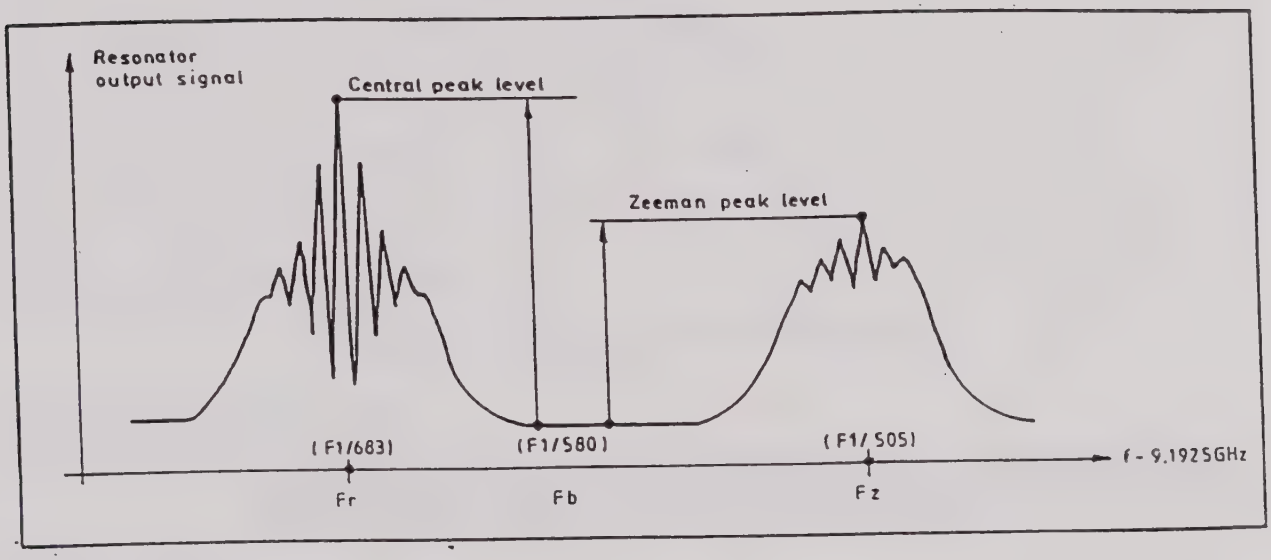


FIGURE 3.7.7 CENTRAL AND ZEEMAN PEAKS: LEVEL MONITORING

3.7.8 Central Peak Symmetry Check

In order not to accidentally center the quartz oscillator on a side resonance (Figure 3.7.8), the control circuits apply to the tube input, during successive test periods T1 and T2, signals with frequencies fr_{30} and fr_{31}, equal to fr ± 386 Hz, symmetrical about the central peak and near the first valleys. These frequencies are supplied by the control circuits, by programming F1/N equal to F1/685 and F1/681, i.e. 131 387 Hz and 132 159 Hz.

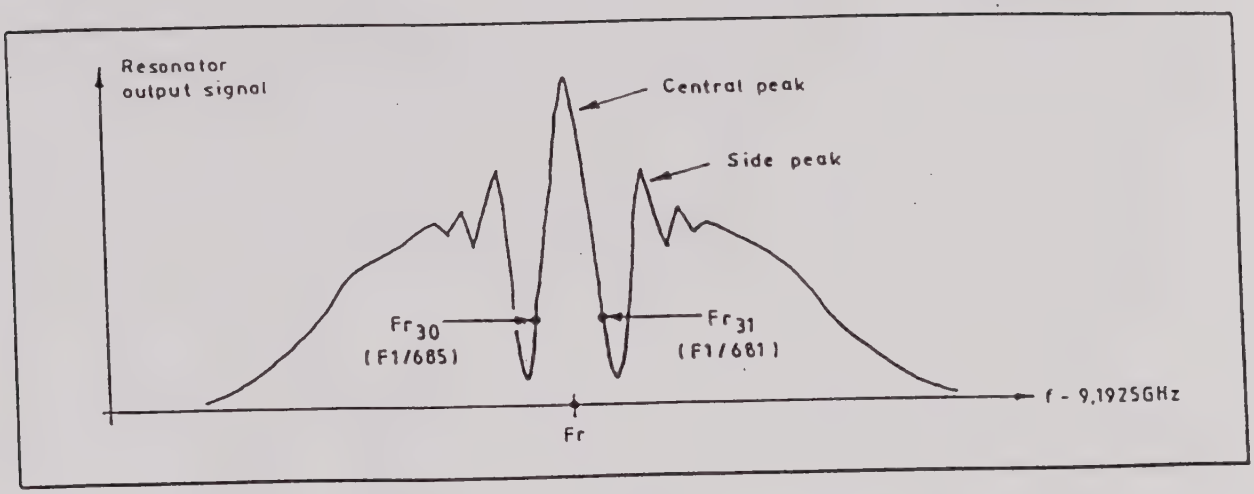


FIGURE 3.7.8 CENTRAL PEAK SYMMETRY CHECK

3.7.9 Central Pedestal Symmetry Check

In a similar way, a check of the quartz oscillator overall centering on the pedestal is done by applying to the tube, during successive test periods T1 and T2, signals with the same frequencies fr_{10} and fr_{11} that are used in the initial phase operation (see para. 3.7.2).

3.7.10 Microwave Power Servo

The microwave power servo lock is done by applying to the tube input, during successive test periods T1 and T2, signals with frequency fr at various power levels controlled by the output stage of 90 MHz to 9.2 GHz multiplier. The associated output levels are used to set the microwave power level so as to maximize the tube output level at the central peak resonance (fr). This servo loop reduces the microwave power variations due to ambient temperature changes.

3.7.11 Other Functions

The central unit also controls the D.C. level at the preamplifier input.

The correction voltage, measured at the HC2 D/A converter output is defined as the mean value of the HC3 integrator output signals in two successive control periods R1 and R2.

Moreover, the central unit can monitor various operating voltages and temperatures, generate alarm levels and cut off the tube power supply in case of major failure.

APPENDIX A

REMOTE CONTROL SOFTWARE

A.1 MONITOR.EXE SOFTWARE

A sample program is available (upon request to marketing/sales) which demonstrates the uses of the RS232 interface for monitoring and control of the FTS 4040A/RS. The software processes and displays the operating parameters of the instrument, including data file creation, and real-time or off-line graphic display of data. The software is a DOS program, for use on an IBM compatible computer. This appendix describes the sample program's features. Paragraph A.4 describes the machine interface, which may be used by programmers to create a custom software interface.

NOTE: This software (monitor.exe) is for demonstration purposes only and is neither guaranteed nor supported by Datum -- Frequency and Time Systems, Inc..

A.2 SETTING-UP THE SERIAL LINK

Connect the FTS 4040A/RS to the PC using the pin assignments of Figure A.2. The 4040A/RS is defined as DTE. Notice that the 4040A/RS only uses CTS as a control line input and that it provides RTS and DTR as control line outputs.

NOTE: The software program to communicate with the FTS 4040A/RS is called MONTOR.EXE and is provided on an IBM double sided-double density 3.5 inch diskette.

Several parameters must be provided to the FTS MONITOR software program at initialization:

The serial port number and the baud rate are to be specified at the start of the program.

An index indicating PC speed must be provided.

Example:

```
2 --> PC serial port number
      (2 ---> port N° 2)

4 --> Baud rate

            1 : 300
            2 : 600
            3 : 1200
            4 : 2400 *
            5 : 4800
            6 : 9600
      (4 ---> 2400 Bauds)

6 --> PC speed index
       Q (slow PC) to 9 (fast PC)
      (6 ---> medium speed)
```

* The 4040A/RS unit is set to communicate at 2400 Baud. Refer to Appendix B to change the baud rate.

ADD 147 AFTER THE COMMAND LINE IN THE DOS PROPERTIES BOX CONSOLE of 4065

The default values are equal to 146.

Example: PROGRAM COMMAND LINE 147 after EXE

C>MONITOR 146 means: PC serial port number : 1

Baud rate : 4 ---> 2400 bauds

Speed index : 6 ---> medium speed

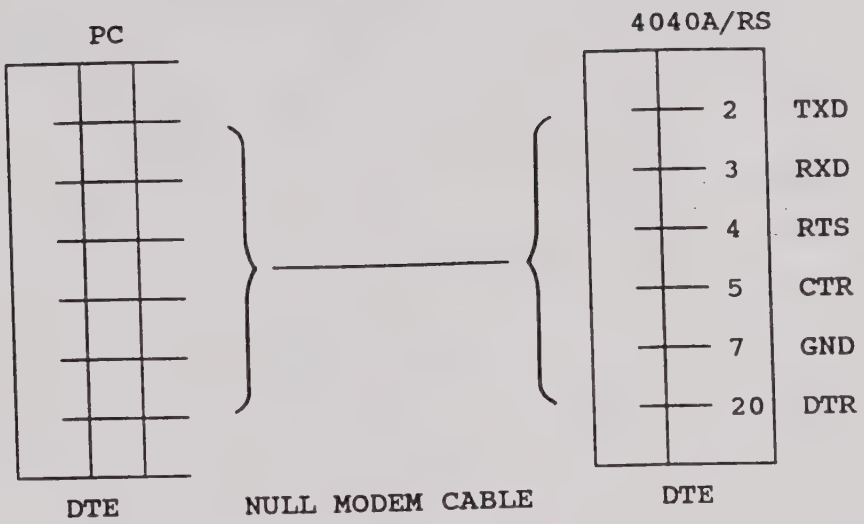


Figure A.2

Serial Link between FTS 4040A/RS and PC

A.3 OPERATING INSTRUCTIONS

After turn-on, the screen displays 2 windows with the following parameters and alarms:

F1-Prmt:F2-Grph:F3-GrSel:F4-GrScl:F5-Inp:F6-Save:F7-Rate:F8--Unit:F9-Nml:F10-Help

- FTS 4065A, 5045A, 4040A/RS Control Monitor -

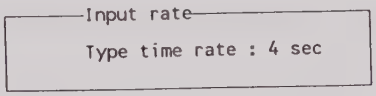
```
Parameters
Rate:  4  0          Unit:00030              Day:032 Time:00h22mn24s

 Ramsey error.: +0000  Offset ctrl. : +0962   +24 V Supply : 24.99

 RabRam error.: +0000  LoopGain fct.:  2.32   Oven voltage : 04.1

 Zeeman error.: -0014  Ramsey C.test: +0000   Spectro.volt.: 15.5

 RabZee error.: +0006  9 GHz Pw ctrl: -2714   HotWire volt.: 0.68

 O.C.X.O cmd. : -0649  +05 V Supply : +5.17   C-Field curr.: 17.9

 Ramsey level :  2502  Temperature  : +42.2   HTEM supply  : 09.3

 C-Field ctrl.: -0077  +15 V Supply : +15.4   Pump current : 000

 Zeeman level :  1707  -15 V Supply : -16.0   ShrtTerm StDv: +193

Alarms
                              LOCKED
```

The upper line displays a reminder of the commands triggered by the function keys <F1> to <F10>.

A.3.1 Parameters

Rate : Shows sampling rate and countdown time to next acquisition. This parameter can be modified using <F7> (serial input rate).

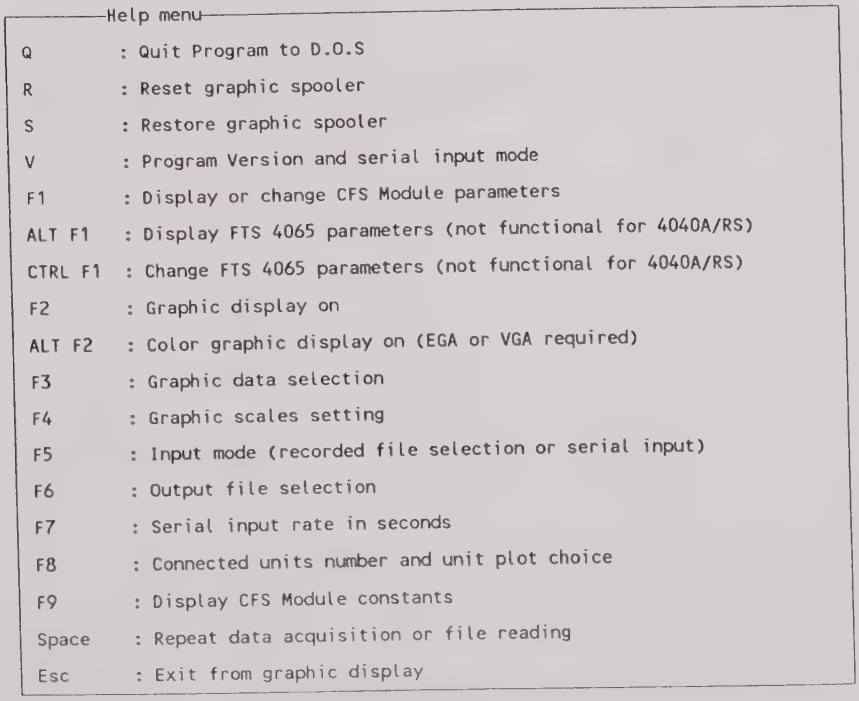
(The sampling rate must be compatible with the PC speed and the number of connected units when data is saved on the disk). Sampling rates which are too short will not allow sufficient time for data acquisition and disk storage.



Unit : Displays the number of the unit under control. This parameter can be modified using <F8>.

Day and Time : Day and Time of measurements. Starts at turn-on and can be modified using <F1>.

- <F10> (Help Menu) displays a window with the explicit functions of the keys.


Help menu
Q : Quit Program to D.O.S
R : Reset graphic spooler
S : Restore graphic spooler
V : Program Version and serial input mode
F1 : Display or change CFS Module parameters
ALT F1 : Display FTS 4065 parameters (not functional for 4040A/RS)
CTRL F1 : Change FTS 4065 parameters (not functional for 4040A/RS)
F2 : Graphic display on
ALT F2 : Color graphic display on (EGA or VGA required)
F3 : Graphic data selection
F4 : Graphic scales setting
F5 : Input mode (recorded file selection or serial input)
F6 : Output file selection
F7 : Serial input rate in seconds
F8 : Connected units number and unit plot choice
F9 : Display CFS Module constants
Space : Repeat data acquisition or file reading
Esc : Exit from graphic display

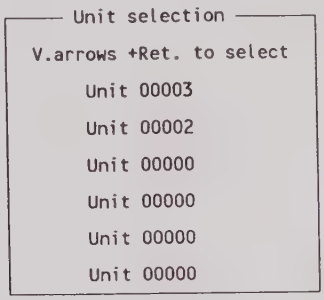
- <F8> (Unit selection) opens a window which lists the connected units. Allows modification of this list and selection of the unit under control.

  CAUTION: ONLY the connected units may be included in this list.

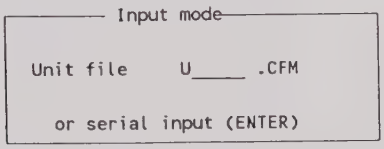
Thus the serial number of disconnected units must be set equal to zero.

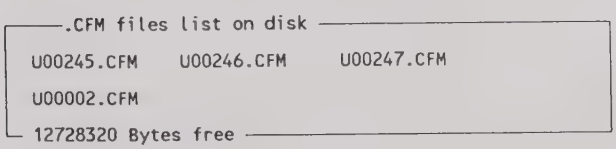
To select the unit under control, position the pointer opposite the chosen unit serial number by means of the <UP> or <DOWN> keys, then press <ENTER>. The new configuration is then stored in an IDENT.DAT file.

By pressing the <ESC> key, the normal procedure is resumed without modification or storage in the IDENT.DAT. file.



- <F5> (Input mode). This function allows off-line reading of a data file. It stops the current data saving that will have to be restarted using <F6> . Enter the file number chosen among the existing .CFM files.

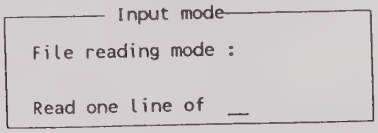




If a .CFM file was selected for input, the next window offers selection of the reading mode for the selected data file.

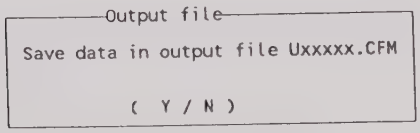
Read one line of 1: reads each line of the data file

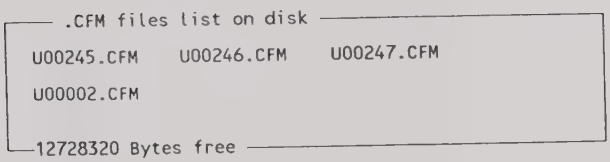
Read one line of N: read every on Nth line which changes the graphic display scale (for instance, read one line of 4 to enlarge the time span of the scale displayed by 4-fold.)



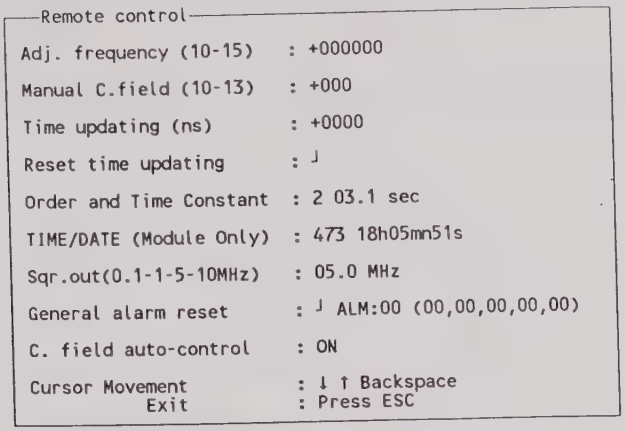
In the "read" mode, keying:

- **<ENTER>** starts the file reading
- **<ESC>** stops the reading
- **<SPACE>** restarts the file reading from the beginning.
- <F6> (Data saving). Keying <Y> opens or reopens N files assigned to the N selected units.





· <F1> (Remote control) opens a window which gives access to the following parameters of the selected unit, thereby allowing their modification.


Remote control
Adj. frequency (10-15) : +000000
Manual C.field (10-13) : +000
Time updating (ns) : +0000
Reset time updating : ┘
Order and Time Constant : 2 03.1 sec
TIME/DATE (Module Only) : 473 18h05mn51s
Sqr.out(0.1-1-5-10MHz) : 05.0 MHz
General alarm reset : ┘ ALM:00 (00,00,00,00,00)
C. field auto-control : ON
Cursor Movement : ↓ ↑ Backspace
Exit : Press ESC

The new values are transmitted by <ENTER>.

The ┘ sign appears when the reset is performed with the <ENTER> key.

· CTRL <F1> is not used by the FTS 4040A/RS module.

- ALT <F1> is not used by the FTS 4040A/RS module.

- <F9> (Nominals) opens a window which displays nominals and constants of the unit under control.

Nominals

Hot-wire voltage nominal	: 0.79V
Spectrometer voltage nominal	: 16.1V
Beam Signal DAC Gain Value	: 002
dF(dt°) model (t°C - F10-13)	: -15:+00 +15:+00 +45:+00 +75:+00
12.6 MHz level nominal	: +0150 mV
Rabi-Zeeman offset (mV)	: -0030 mV
Console language	: English
Unit comments	: 10/88
CFS Module Software Version	: ver m.n

A.3.2 Alarms

The message in the window center provides information about the state of the unit.

The variable string acquired from the RS232 port contains a substring as such: "ALM:SS (nn,nn,nn,nn,nn)" where: ss is a two digit status string and nn is a two digit alarm number.

The alarm states and messages below have their associated numbers to illustrate the alarms reporting structure. See paragraph A.4 for more detail on the variables data string.

"ALM:01"INITIALIZATION	:	Start-up phase, shorter than 45 min. No error detection during start-up.
"ALM:00"LOCK	:	No fault.
"ALM:10"MINOR ALARM	:	Small error with no danger to the unit.
"ALM:11"MAJOR ALARM	:	Serious error and depending on type.

Messages are classified in three alarm groups: Minor, Major Non-Fatal and Major Fatal. The unit stops operating after a fatal error detection.

Minor Alarm Messages:

08	Oscillator cmd. >90% or >95%
18	Beam Gain DAC Near Limit

Major Alarm Messages: (without tube shutdown):

01	Ramsey-backgrnd	> 3V or < 2V
02	Rabi-Ramsey error	> 40 mV
03	Rabi-Zeeman error	> 160 mV
04	Spectrometer voltage drift	
05	C-Field current	<17 or >20 mA
06	EM supply	<7V or >11 V
07	DAC input error out 5 to 95%	
08	Oscillator Cmd	>90% or >95%
09	Internal temperature	>80°C
10	Not Used	
11	12.6 MHz Power out of range	
12	+5.1V Supply voltage	>± 0.40 V
13	+15 V Supply voltage	>± 1.5 V
14	-15 V Supply voltage	>± 1.5 V
15	EEPROM Write Error	
16	Unit Restart	
17	Module Configuration Lost	

Major Alarm Messages: (resulting in tube shutdown):

F1 Excess oven heating > 10V/45 min
F2 Excess O.C.X.O heating
F3 Hot-Wire volt error > ± 0.16V
F4 Ion-Pump current > 240 μA
F5 24V Supply voltage <20V >30V

Reset the alarms <F1> after correcting the error.

A.3.3 Graphic Display

- <F3> (Graphic data selection) opens a window displaying the parameters. Selection is made with the <UP> and <DOWN> or with the field first character keys, then by pressing <SPACE>.

The selection consists of 1 to 6 parameters maximum. The display format will automatically adapt to the number of chosen parameters.

Normal operation is resumed by pressing <ENTER>.

Selection is not modified by entering the window and exiting by means of <ESC>.

```
Graph parameters
    Moving     : Vert. or hor. arrows or 1st char.
    Selection  : Space
    Out        : Return
    Select 6 parameters max.

Ramsey error.:   Offset ctrl. :   +24 V Supply :
RabRam error.:   LoopGain fct.:1  Oven voltage :
Zeeman error.:   Ramsey C.test:2  Spectro.volt.:
RabZee error.:   9 GHz Pw ctrl:   HotWire volt.:
O.C.X.O cmd. :   +05 V Supply :   C-Field curr.:
Ramsey level :   Temperature  :3  HTEM supply  :
C-Field ctrl.:   +15 V Supply :   Pump current : <--
Zeeman level :   +15 V Supply :   ShrtTerm StDv:
```

- <F2> (Graphic display). The parameters chosen above are graphically displayed. The horizontal scale is given in the last line. An example is shown in Figure A3.3.

S = X total scale

C = X center offset

These scales can be modified using <F4>. The Y time scale is given in min/div. and depends on the sampling rate at the time of filing (see F5). The total scale has 12 divisions.

To move out of the graphic mode back to the read mode press <ESC>. Once in the read mode;

- <F2> displays the last graph.

- <R> restarts the graphic display.

- <S> restores the graphic display erased by <R>.

In real-time display (serial port), the data display does not stop when it reaches the end of the time scale but starts at the top again and overprints the first traces.

In off-line display , the file reading stops at the end of the time-scale, awaiting a "print display" order by means of the <SPACE> or <SHIFT-PrtSc> keys.

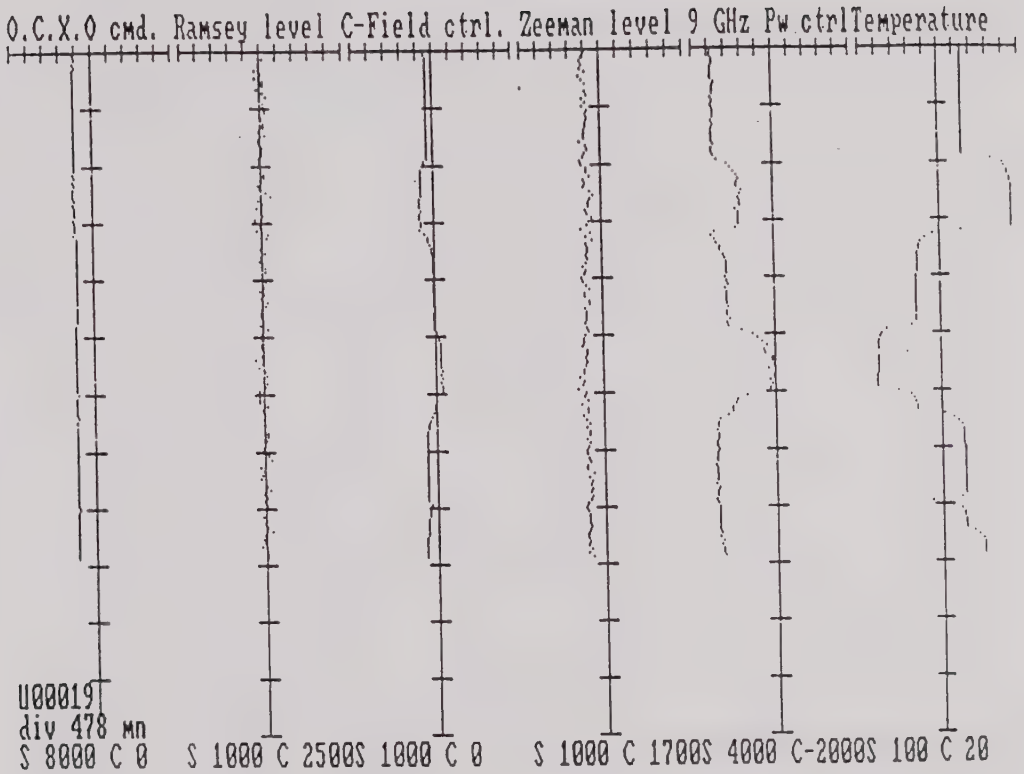

O.C.X.O cmd. Ramsey level C-Field ctrl. Zeeman level 9 GHz Pw ctrlTemperature
U00019
div 478 mn
S 8000 C 0
S 1000 C 2500S 1000 C 0
S 1000 C 1700S 4000 C-2000S 100 C 20

Figure A.3.3
Graphic Display Example (response to a temperature step)

- <F4> (Graphic scales) displays the scales in use. The method is the same as for the other window: to change a value, first select the field, press <ENTER>, enter the new value and press <ENTER> again.

  To move out of the window key <ENTER>. These keys store the scales in a SCALE.DAT file.

If no files exist at the start of the program, default values are used.

Default values are shown below.

Graph scale

```
Moving      : Vert. or hor. arrows or 1st char.
Modify      : SPACE  --> new value --> ENTER
Out         : Type Space or ENTER.
```

Scale - Axis			Scale - Axis		
Ramsey error.:	400	0	+05 V Supply :	1	5
RabRam error.:	200	0	Temperature :	100	30
Zeeman error.:	400	0	+15 V Supply :	10	15
RabZee error.:	200	0	-15 V Supply :	10	-15
O.C.X.O cmd. :	8000	0	+24 V Supply :	10	24
Ramsey level :	1000	2500	Oven voltage :	10	5
C-Field ctrl.:	8000	0	Spectro.volt.:	20	10
Zeeman level :	1000	1700	HotWire volt.:	.5	.75
Offset ctrl. :	8000	0	C-Field curr.:	20	10
LoopGain fct.:	5	2.5	EM supply :	5	10
Ramsey C.test:	200	0	Pump current :	200	100
9 GHz Pw ctrl:	4000	-2000	ShrtTerm StDv:	1000	500

A.3.4 Miscellaneous functions

<Q> key : Quits program to D.O.S.

<R> key : Resets graphic spooler. (The spooler is a section of memory which stores one screenful of selected graphical data. Re-setting the spooler permits the overwriting of this section of memory with incoming real time data).

<S> key : Restores graphic spooler. (Restoring the spooler permits the viewing of graphical data that has been previously stored in this section of memory).

<V> key : Program version and serial input mode.

```
PC software version m.nn
      FTS 4065 CONTROL MONITOR   DWG #11214-001
      FTS INC. (800)544-0233, (508)927-8220
Serial RS.232: COM port 1,2400 baud ,Odd,7 bits, 2 stops
```

A.4 Format of ASCII Strings Transmitted & Received at the PC

When not using the FTS MONITOR.EXE software application, it is possible to directly send and receive information from the instrument.

Communicating with the 4040A/RS directly through a computer's serial port is accomplished using a variety of ASCII character sequences. The formats of these sequences are described below.

Unless otherwise noted:

a). Square brackets indicate control characters as follows:

Notation	ASCII code (decimal)
[STX]	02
[ETX]	03
[CR]	10
[LF]	13

b). n indicates a digit from 0 to 9.

c). _ (underscore) indicates a space (ASCII code 32)

1. REMOTE CONTROL ON

Format: [STX]T*2_nnnnn_[ETX]

Note: nnnnn represents the 5-digit serial number of the 4040A/RS. Use leading zeros as required to provide 5 digits.

2. REMOTE CONTROL OFF

Format: [STX]T*1_nnnnn_[ETX]

Note: nnnnn represents the 5-digit serial number of the 4040A/RS.

A.4 Format of ASCII strings transmitted & received at the PC (cont'd)

3. REQUEST VARIABLES DATA MESSAGE

Format: [STX]D*1_nnnnn_[ETX]

NOTE: nnnnn represents the 5-digit serial number of the 4040A/RS. In response to this command the 4040A/RS will return a string of 338 characters (including control characters). Each variable is positioned in the string according to the following table:

Position in string	Contents	Example
1-3	Control characters	[STX][CR][LF]
4-11	ID number plus space	ID00001_
12-15	Day Count plus space	234_
16-26	Time plus space	23h59mn59s_
27-28	Servo order plus space	2_
29-32	Operating mode plus space	R+Z_
33-54	Alarms state plus space	ALM:00(00,00,00,00,00)
55-60	C-field adjustment plus space	C +015_
61-69	Frequency fine tuning plus space	F -000000_
70-77	+24 volt power supply plus space	+25.23V_
78-83	Filtering time constant	Ct10.1
84-85	Control characters	[CR][LF]
86-90	Clock servo voltage diff. (input)	R+013
91-98	Clock pedestal servo voltage diff. (input)	RR_+0012
99-103	Zeeman servo voltage diff. (input)	Z+008
104-111	Zeeman pedestal servo voltage diff. (input)	RZ +0036
112-118	Oscillator servo output voltage	AR-1318
119-124	Clock peak to background level diff.	PR2495
125-131	Zeeman servo output voltage	AZ+0080
132-137	Zeeman peak to background level diff.	PZ1677
138-144	Preamplifier DC level servo output voltage	AO+0822
145-151	Numerical gain	GN*3.28
152-158	Clock(Ramsey) peak symmetry check	LA+0001
159-165	Microwave power servo control voltage	Pu-0408
166-167	Control characters	[CR][LF]
168-174	+5 volt supply plus space	+5.17V_
175-181	Internal case temperature plus space	T+35.5_
182-188	+15.5 volt supply plus space	+15.4V_
189-195	-15.5 volt supply plus space	-16.0V_
196-199	Quartz oscillator cold (warm) plus space	OLc_
200-206	Cesium oven supply voltage plus space	FO04.5_
207-213	Mass spectrometer voltage plus space	VS15.5_
214-220	Cesium tube ionizer voltage plus space	VF1.66_
221-227	C-field coil current plus space	IC17.9_
228-234	HTEM control voltage plus space	HT10.6_
235-240	Ion pump current plus space	IP025_
241-247	Standard Deviation of clock servo voltage difference over 30s	+137 mV
248-249	Control characters	[CR][LF]

A.4 Format of ASCII strings transmitted & received at the PC (cont'd)

4. REQUEST CONSTANTS DATA MESSAGE

Format: [STX]D*2_nnnnn_[ETX]

Note: nnnnn represents the 5-digit serial number of the 4040A/RS.

In response to this command the 4040A/RS will return a string of 145 characters including control characters). Each variable is positioned in the string according to the following table:

Position in string	Contents	Example
1-3	Control characters	[STX][CR][LF]
4-11	ID number plus space	ID00001_
12-15	Day Count plus space	234
16-25	Time plus space	23h59mn59_
26-34	Nominal spectrometer voltage plus space	Vs_14.0V_
35-43	Nominal tube ionizer voltage plus space	Vf_1.07V_
44-52	Beam Signal DAC Gain Value	GDAC_002_
53-60	F(t^{O}) correction model at -15 °C plus space	-15:+10_
61-68	F(t^{O}) correction model at +15 °C plus space	+15:+00_
69-76	F(t^{O}) correction model at +45 °C plus space	+45:-03_
77-83	F(t^{O}) correction model at +75 °C plus space	+75:+04_
84-85	Control characters	[CR][LF]
86-93	Nominal 12.6MHz level plus space	Pi+0345_
94-101	Zeeman offset (asymmetry compensation) plus space	Oz-0045_
102-113	Auxiliary output signal frequency plus 2 spaces	Fo:05.0MHz__
114-120	Console mode language plus space	CDU:GB_
121-135	Comments (TXT: plus 10 characters plus space)	TXT:2/25/91____
136-142	Program version	ver_5.0
143-145	Control characters	[CR][LF][ETX]

APPENDIX B

THIS SECTION DELETED INTENTIONALLY

APPENDIX C

APPLICABILITY:
OPTION 063: DS1 FREQUENCY SYNTHESIZER

APPENDIX C

CESIUM TIME AND FREQUENCY STANDARD OPERATING MANUAL P/N 08518-001-00000

Applicability: Option 063, DS1 Frequency Synthesizer

C1.0 GENERAL INFORMATION

This addendum provides supplemental information to the FTS 4040A/RS Operating Manual when Option 063 is included. Option 063 cannot be combined with Option 064.

C1.1 General Description

Option 063 adds a DS1 Telecommunications Synthesizer PCB Assembly, A2, to the FTS 4040A/RS. With Option 063, the FTS 4040A/RS can serve as a stand alone Stratum 1 Master Clock or as a component of a master clock system.

Option 063 adds the following outputs to the rear panel of the instrument:

- A balanced 1.544 MHz, framed all ones, DS1 signal.
- An 8 kHz, TTL signal synchronous with the DS1 Frame Markers.
- A 1.544 MHz TTL clock.

All three outputs are phase-locked to a 10 MHz reference input provided by the Cesium Frequency Module, A1.

The DS1 output is switch selectable (via a 4-position terminal block on the PCB) to provide either a D4 or Extended Superframe (ESF) format. Figure C1 provides an illustration of the D4 and ESF formats. As shipped from the factory, the switches are set to provide the D4 format.

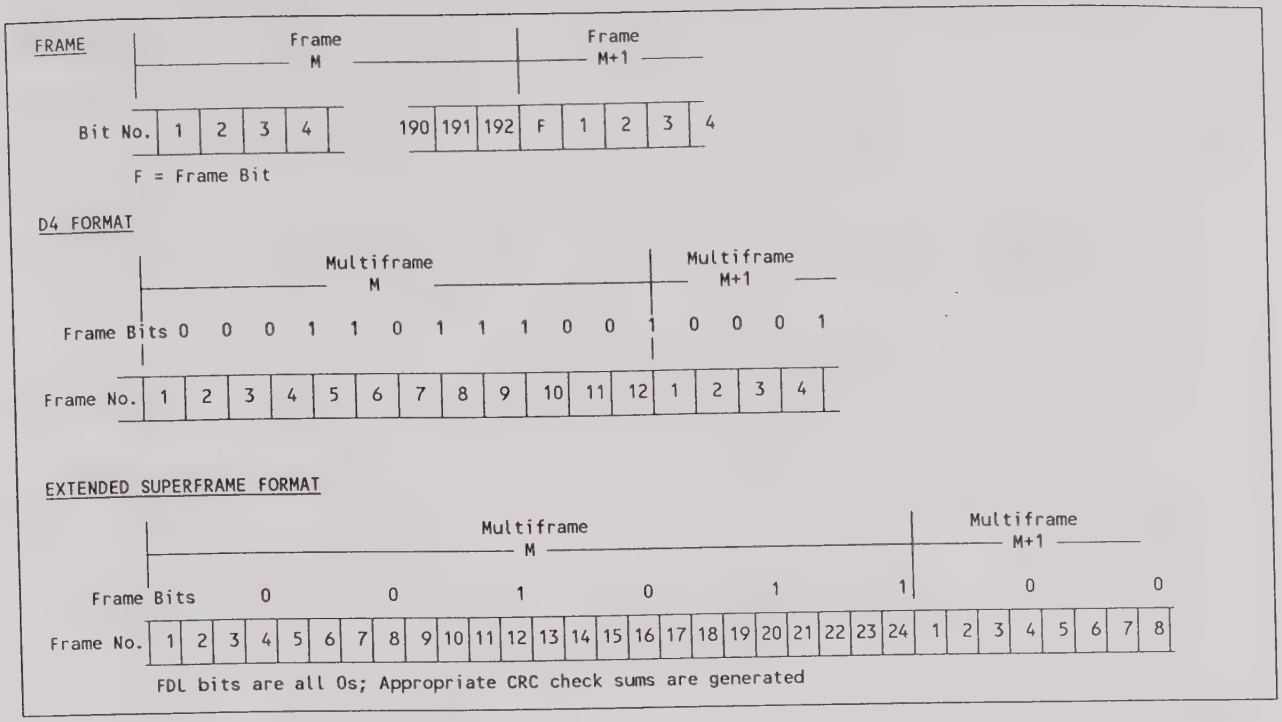

FRAME
Frame M
Frame M+1
Bit No. 1 2 3 4 190 191 192 F 1 2 3 4
F = Frame Bit
D4 FORMAT
Multiframe M
Multiframe M+1
Frame Bits 0 0 0 1 1 0 1 1 1 0 0 1 0 0 0 1
Frame No. 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
EXTENDED SUPERFRAME FORMAT
Multiframe M
Multiframe M+1
Frame Bits 0 0 1 0 1 1 0 0
Frame No. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8
FDL bits are all 0s; Appropriate CRC check sums are generated

Figure C1 Frame, D4 and Extended Superframe Formats

The following input is added to the rear panel:

Frame Synchronization

This input allows the DS1 and Frame Alignment output signals to be synchronized to an external reference.

A contact closure summary alarm is added to the rear panel MONITOR connector.

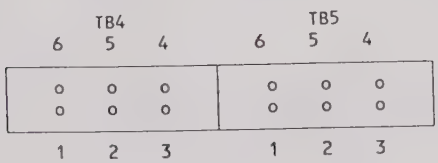
Table C1 is a list of specifications applicable to Option 063 and supplements Table 1-1 in the manual.

Table C1 Specifications, DS1 Synthesizer

OUTPUTS	
DS1	
Signal Type	DS1, balanced
Frequency	1.544 MHz
Format	Framed all 1's (D4 or ESF)
Jitter	<0.05 U.I.
Connectors (connected in parallel)	Twin - BNC, receptacle (31-223, Amphenol) Mating Connector (31-224, Amphenol) and WECO type receptacle (MT-332B, Switchcraft) Mating Connector (483, Switchcraft) and Bantom type receptacle (TT-32BDC, Switchcraft) Mating Connector (TT253, Switchcraft)
Cable Length	0-133 ft (ABAM Cable)
Frame Marker	
Signal Type	TTL
Frequency	8 kHz
Connector	BNC
TTL clock	
Signal Type	TTL
Frequency	1.544 MHz
Connector	BNC
INPUTS	
Frame Synchronization	
Signal Type	TTL compatible, active low
Frequency	8 kHz or submultiple of 8 kHz
Connector	BNC
MONITORS	
Summary Alarm	
Type of Alarm	Contact Closure
Contact Rating (maximum)	5 A at 30 V dc
Connector	J11 pins 6, 7, & 8; rear panel
CONTROLS	
D4/ESF	4-Position Terminal Block on PCB

Table C1 Specifications, DS1 Synthesizer (cont'd)

JUMPER CONFIGURATION			
CONDITION		4040 (D4)	4040 (ESF)
DS1 1.544MB/S Option 063 Balanced	TB1	3-4	3-4
	TB2	B-C	B-C
	TB3	N/C	N/C
	TB4	2-5	N/C
	TB5	2-5	N/C
CEPT 2.048MB/S Option 064 Balanced	TB1	1-6,2-5,3-4	
	TB2	A-B	
	TB3	N/C	
	TB4	1-6,2-5	
	TB5	1-6,2-5	



DB: TB4 2-5 shorted
TB5 2-5 shorted

ESF: TB4 all removed
TB5 all removed

C2.0 OPERATION

C2.1 Connections

All Option 063 external connections are made at the FTS 4040A/RS rear panel. The TTL CLOCK output uses BNC connectors. The DS1 signal is presented on the rear panel connectors J1, J2 and J3. (Note: These connectors are connected in parallel).

Note that Alarm detection circuitry turns off the balanced DS1 output when a fault is detected or when proper lock to the cesium resonance has not been achieved. No balanced DS1 output is present during warm-up and lock acquisition of the FTS 4040A/RS.

The Summary Alarm relay contacts are available at pins 6, 7, and 8 of the rear panel MONITOR connector.

C2.2 Operating Instructions

C2.2.1 Synchronizing

The frame alignment of the DS1 output can be synchronized to an external reference. It is suggested that a TTL pulse with a repetition rate of 8 kHz (or a submultiple of 8 kHz) signal be used for synchronization because the frames repeat at an 8 kHz rate.

To synchronize, briefly apply the reference signal to the rear panel BNC connector labeled SYNC.

Another FTS 4040A/RS/063 may be used as a reference by connecting its **8 KHZ** FRAME MARKER output to the FRAME SYNC input of the unit being synchronized.

C2.2.2 D4/Extended Superframe Selection

The DS1 format may be switched from D4 to ESF by setting a 4-position terminal block assembly located on the Synthesizer Assembly. Contact FTS Technical Service for details.

C2.3 Monitoring

System operating status is monitored in the same manner as described in the manual with the following changes:

- Operational status of the DS1 Synthesizer is available at the rear panel MONITOR connector at pins 6, 7, and 8.

When the DS1 Synthesizer is in normal operational condition, pins 6 to 8 are open and pins 7 and 8 are shorted to each other. In a DS1 Alarm condition, pins 6 and 8 are shorted and pins 7 to 8 are open.

A DS1 alarm condition exists when:

a) proper lock to the cesium resonance has not been achieved (FTS 4040A/RS front panel LOCK indicator not illuminated).

b) a malfunction within the DS1 Synthesizer has occurred.

The balanced DS1 signal is turned off during a DS1 alarm condition.

C2.3.1 Loss of Signal

A DS1 signal loss can be caused by:

- Loss of internal 10 MHz reference input signal to the assembly,
- Loss of DS1 Synthesizer phase-lock, or
- Loss of the cesium lock (or before the unit has achieved lock during warm-up).

If the cesium module is operational and the fault exists only with the DS1 Synthesizer Assembly, the FTS 4040A/RS front panel LOCK indicator is lit. When the OP ALARM indicator is lit and the LOCK indicator is not lit, the problem is most likely related to the cesium module.

C3.0 THEORY OF OPERATION

C3.1 Functional Description

The DS1 Synthesizer consists of:

- A Digital Phase-locked Synthesizer
- DS1 Format Generator and Synchronization Circuit
- Frame Detector Circuit
- Alarm Circuitry.
- Power Converter

Refer to Figure C2 for a block diagram of the DS1 Synthesizer Assembly.

C3.1.1 Digital Synthesizer

The digital synthesizer section phase-locks a 6.176 MHz VCXO to a 10 MHz reference signal that is supplied by the Cesium Frequency Module, A1. Both the 6.176 MHz and the 10 MHz signals are digitally divided, phase compared, and integrated to provide a control voltage to the VCXO.

The first divide-by-four stage yields a 1.544 MHz signal. This signal is distributed to:

- The DS1 Format Generating Circuitry to provide the DS1 clock
- The rear panel as a buffered 1.544 MHz TTL output.

C3.1.2 DS1 Format Generator and Synchronization Circuit

C3.1.2.1 DS1 Formatting

The required DS1 formatted TTL output is provided by a Serial Receiver/Transmitter driven by the 1.544 MHz clock signal. The formatted data is applied to a T1 Line Interface device.

The Line Interface device transforms the TTL signal (from the serial transmitter) into the appropriately shaped Alternating Mark Inverted (AMI) pulse.

C3.1.2.2 DS1 Synchronization

The Receiver/Transmitter accepts an external SYNC signal (see Table B1 for specifications) and synchronizes the start of the frame to the sync reference. Synchronization occurs on the next clock pulse after the SYNC input has returned to a logic "1".

C3.1.3 Frame Detector

The Frame Detector accepts a five-bit BCD word from the Receiver/Transmitter that is the binary value of the channel being transmitted. At the start of the next frame, logic circuitry detects a binary "00000" and provides a Frame Marker output pulse.

C3.1.4 Alarm Circuitry

Alarm circuitry is provided by relay contacts that are brought to the FTS 4040A/RS's rear panel MONITOR connector. The relay is activated by a loss of the 10 MHz reference input signal, a loss of the 6.176 MHz phase-lock, a loss of Cesium lock, or a failure of the DS1 driver circuit.

C3.1.5 Power Converter

The DS1 Synthesizer Assembly accepts +5 V dc and converts it to ±12 V dc. A DC to DC IC regulator is used.

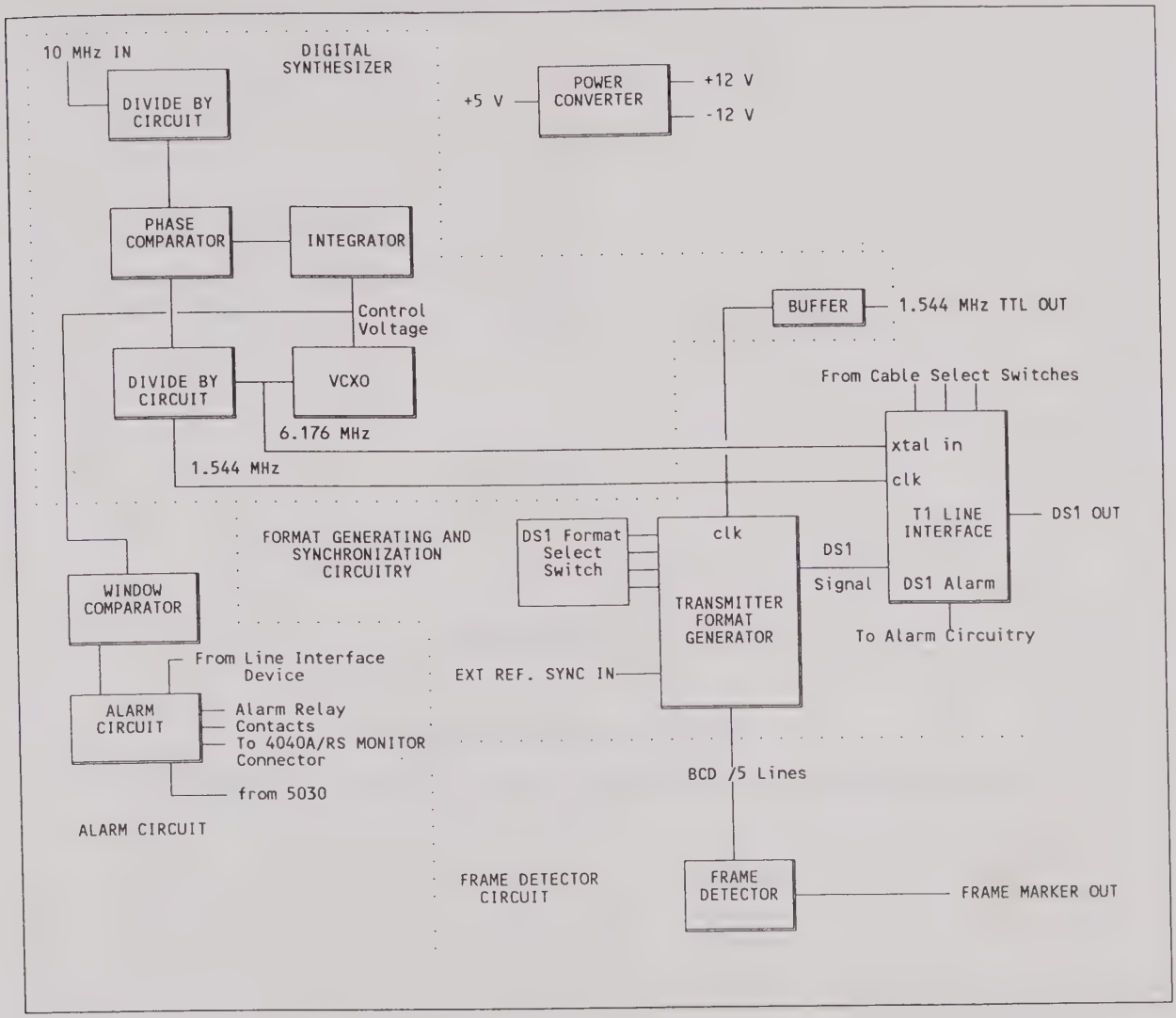


Figure C2 DS1 Synthesizer Assembly Block Diagram

APPENDIX D

APPLICABILITY:
OPTION 064: CEPT FREQUENCY SYNTHESIZER

Appendix D

CESIUM TIME AND FREQUENCY STANDARD OPERATING MANUAL P/N 08513-001-00000

Applicability: Option 064, CEPT Frequency Synthesizer

D1.0 SCOPE

This addendum provides supplemental information to the FTS 4040A/RS Operating Manual when Option 064 is included.

Option 064 cannot be combined with Option 063.

D2.0 OPTION DESCRIPTION

Option 064 adds a CEPT Telecommunications Synthesizer PCB Assembly to the FTS 4040A/RS. With Option 064, the FTS 4040A/RS can serve as a Stratum 1 Master Clock or as a component of a master clock system.

Option 064 adds the following outputs to the rear panel of the instrument:

- A balanced 2.048 MHz CEPT signal.
- An 8 kHz, TTL signal synchronous with the CEPT Frame Markers.
- A 2.048 MHz TTL clock.

All three outputs are phase-locked to a 10 MHz reference input provided by the Cesium Frequency Module, A1.

Figure D1 provides an illustration of CEPT format.

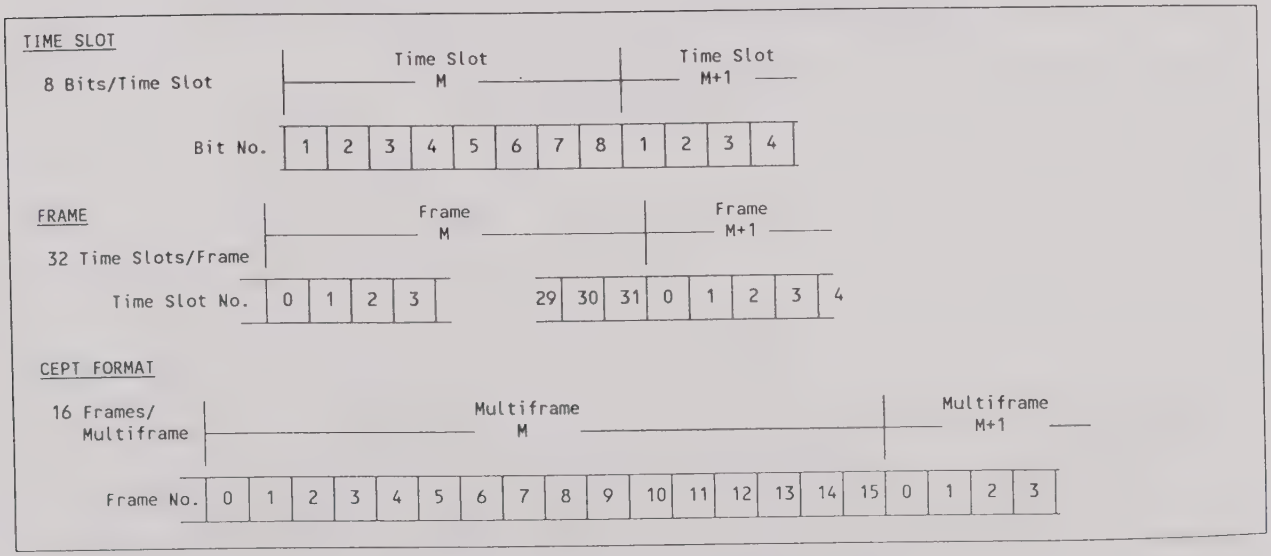

TIME SLOT
8 Bits/Time Slot
Time Slot M
Time Slot M+1
Bit No. 1 2 3 4 5 6 7 8 1 2 3 4
FRAME
32 Time Slots/Frame
Frame M
Frame M+1
Time Slot No. 0 1 2 3
29 30 31 0 1 2 3 4
CEPT FORMAT
16 Frames/ Multiframe
Multiframe M
Multiframe M+1
Frame No. 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0 1 2 3

Figure D1 Time Slot, Frame, and CEPT Formats

The following are added to the rear panel:

- Frame SYNChronization input for synchronizing the framing of the balanced CEPT output and a FRAME MARKER output.
- A contact closure summary alarm.

Table D1 is a list of specifications applicable to Option 064 and supplements Table 1-1 in the manual.

D2.1 Functional Description

Refer to Figure D2 for a block diagram of the CEPT Synthesizer Assembly.

The synthesizer phase-locks a VCXO to a 10 MHz reference signal supplied by the Cesium Frequency Module, A1. Both the VCXO and the 10 MHz signals are digitally divided, phase compared, and integrated to provide a control voltage to the VCXO.

The output of the VCXO is digitally divided to produce a 2.048 MHz signal. This signal is:

- Supplied to the rear panel as a buffered TTL output
- Formatted and output as a balanced CEPT signal.

Alarm detection circuitry turns off the balanced CEPT output when a fault is detected in the CEPT synthesizer or when the proper lock to the cesium resonance has not been achieved. Note that no balanced output is present during FTS 4040A/RS warm-up and lock acquisition.

A Frame Detector circuit determines the start of each frame and provides a Frame Marker output pulse with each occurrence.

The CEPT Synthesizer Assembly accepts +5 V dc and converts it to ±12 V dc. A DC/DC IC regulator is used.

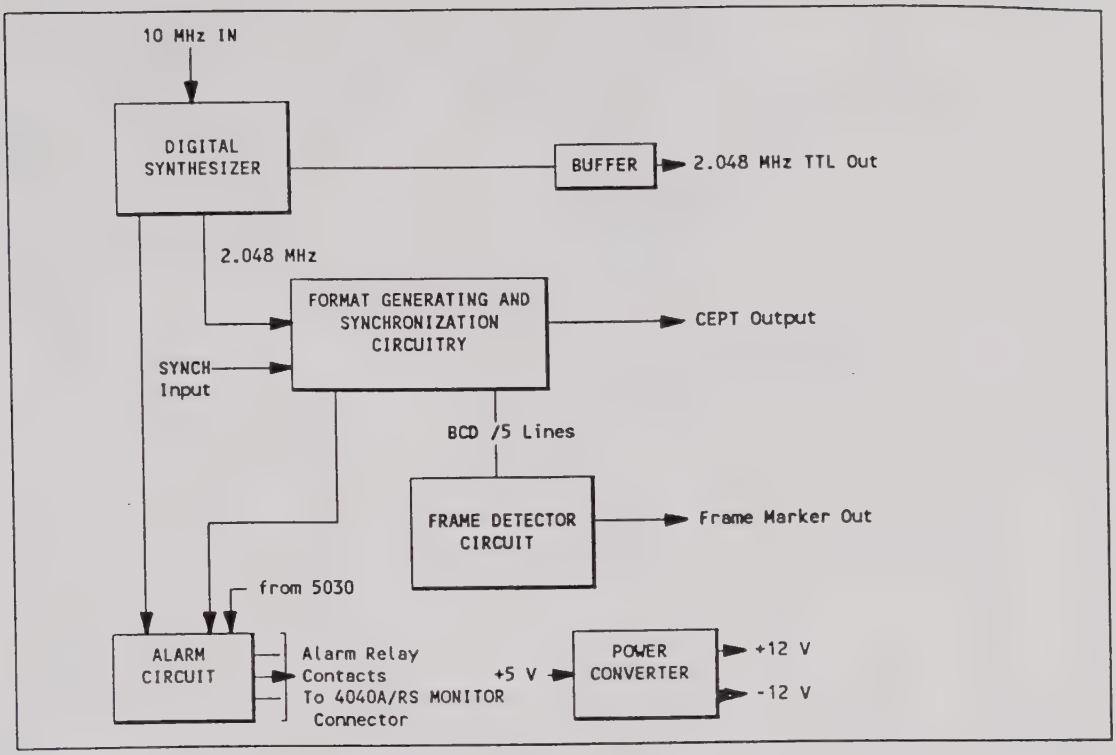


Figure D2 CEPT Synthesizer Assembly Block Diagram

D2.2 Specifications

Table D1 Specifications, CEPT Synthesizer

OUTPUTS	
CEPT	
Signal Type	CEPT, balanced
Frequency	2.048 MHz
Format	Framed all 1's
Jitter	<0.05 U.I.
Connector	
Balanced	120 Ω, Twin-BNC receptacle (31-223, Amphenol) Mating Connector (31-224)
Unbalanced	75 Ω, BNC
Frame Marker	
Signal Type	TTL
Frequency	8 kHz
Connector	BNC
TTL clock	
Signal Type	TTL
Frequency	2.048 MHz
Connector	BNC
INPUTS	
Frame Synchronization	
Signal Type	TTL compatible, active low
Frequency	8 kHz or submultiple of 8 kHz
Connector	BNC
MONITORS	
Summary Alarm	
Type of Alarm	Contact Closure
Contact Rating (maximum)	5 A at 30 V dc
Connector	J8 pins 6, 7, & 8; rear panel1

D3.0 INSTALLATION

D3.1 Connections

All Option 064 external connections are made at the FTS 4040A/RS rear panel. The FRAME SYNC input, Frame Marker 8 kHz output, use a BNC connector; the TTL CLOCK output uses a BNC connector. The balanced CEPT output uses a twin-BNC receptacle. The CEPT output connector is labeled DS1.

The Summary Alarm relay contacts are available at pins 6, 7, and 8 of the rear panel MONITOR connector.

D4.0 OPERATING INSTRUCTIONS

D4.1 Synchronizing

The frame alignment of the CEPT output can be synchronized to an external reference. See Table D1 for input signal requirements.

To synchronize, briefly apply the reference signal to the rear panel BNC connector labeled **8 KHZ**. Another FTS 4040A/RS/064 may be used as a reference by connecting its CLOCK output to the SYNC input to the unit being synchronized. Synchronization occurs on the next clock pulse after the SYNC input has returned to a logic "1".

D4.2 Monitoring

Instrument status is monitored as described in the manual with the following changes:

- Operational status of the CEPT Synthesizer is available at the rear panel MONITOR connector at pins 6, 7, and 8.

When the CEPT Synthesizer is in normal operational condition, pin 6 to 8 are is open and pins 7 and 8 are shorted to each other. In a CEPT Alarm condition, pins 6 and 8 are shorted and pins 7 to 8 are open.

A CEPT alarm condition exist when:

a) proper lock to the cesium resonance has not been achieved (FTS 4040A/RS front panel LOCK indicator not illuminated).

b) a malfunction within the CEPT synthesizer has occurred.

The balanced CEPT signal is turned off during a CEPT alarm condition.

D4.3 Loss of Signal

A CEPT signal loss can be caused by:

- Loss of internal 10 MHz reference input signal to the assembly,
- Loss of CEPT Synthesizer phase-lock, or
- Loss of the cesium lock (or before the unit has achieved lock during warm-up).

If the cesium module is operational and the fault exists only with the CEPT Synthesizer Assembly, the front panel LOCK indicator is lit. When the OP ALARM indicator is lit and the LOCK indicator is not lit, the problem is most likely related to the cesium module.

APPENDIX E

OPTION 003, 1 PPS

Appendix E

CESIUM TIME AND FREQUENCY STANDARD OPERATING MANUAL P/N 08518-001-00000

Applicability: Option 003, 1 PPS

E1.0 GENERAL INFORMATION

This addendum provides supplemental information to the FTS 4040A/RS Operating Manual when Option 003 is included. Option 003 cannot be combined with Option 063 or 064.

E1.1 General Description

A block diagram of the 1 PPS circuit is shown below in Figure 1.

A 10 MHz TTL signal from the Cesium Module drives a divide-by-10^7 counter to produce a 1 pps, 20 μs wide timing pulse. The pulse is buffered to produce a 10 V peak output signal on the rear panel (see Figure E2).

An external reference pulse on the rear panel (see Figure E2) may be used to synchronize the 1 pps output signal to within $\pm$150 ns of the reference pulse. The reference pulse is enabled by momentarily (1 to 2 seconds) depressing the 1 PPS SYNC switch. The switch is recessed behind the front panel (refer to the front panel diagram in Section 1). The reference pulse clears the counters on the rising edge of the first reference pulse and releases the counters on the rising edge of the second reference pulse.

A timing diagram of the synchronizing action is shown in Figure E3.

E2.0 SPECIFICATIONS

OUTPUT	
Amplitude	>2.4 V peak into 50 ohm load
Width	20 μs $\pm$10%
Rise Time	<5 ns
Fall Time	<10 ns
INPUT	
Amplitude	+2 to + 10 V peak
Width	100 ns min., 100 μs max.
Rise Time	<50 ns
Input Impedance	50 ohms

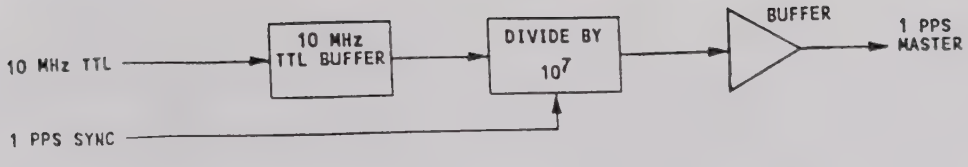


Figure E1 Block Diagram

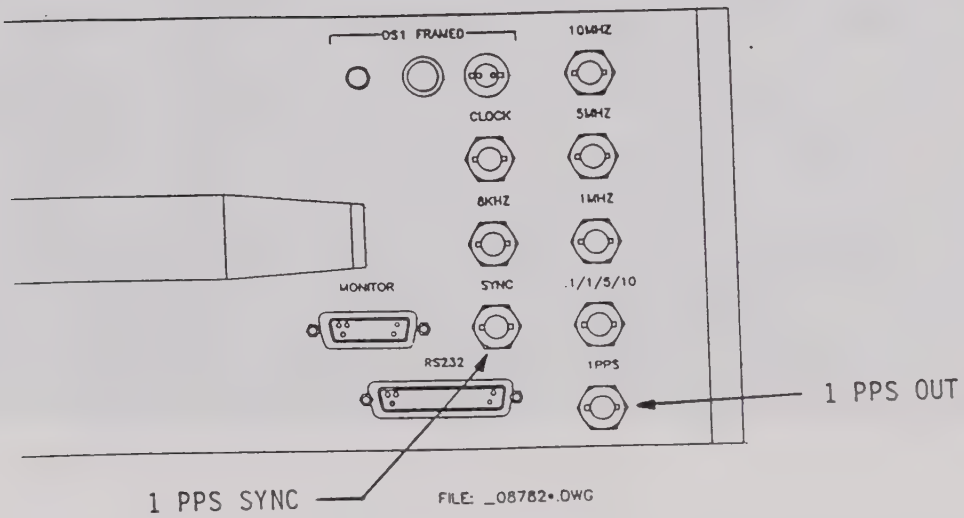


Figure E2 FTS 4040A/RS (Rear Panel) 1 PPS Out and 1 PPS Sync Connector Locations

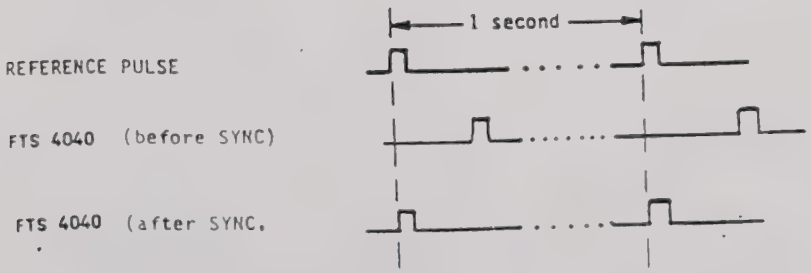
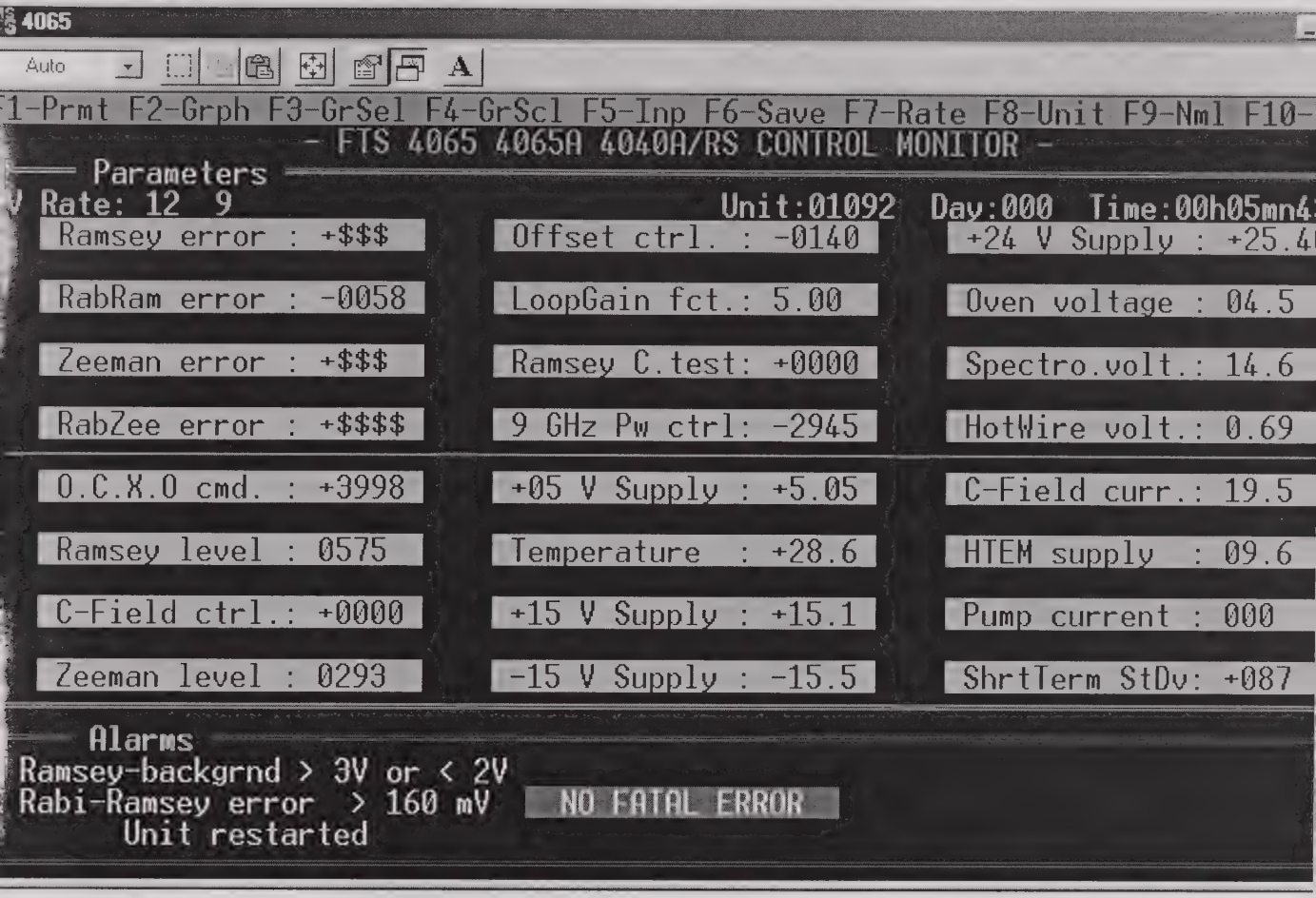
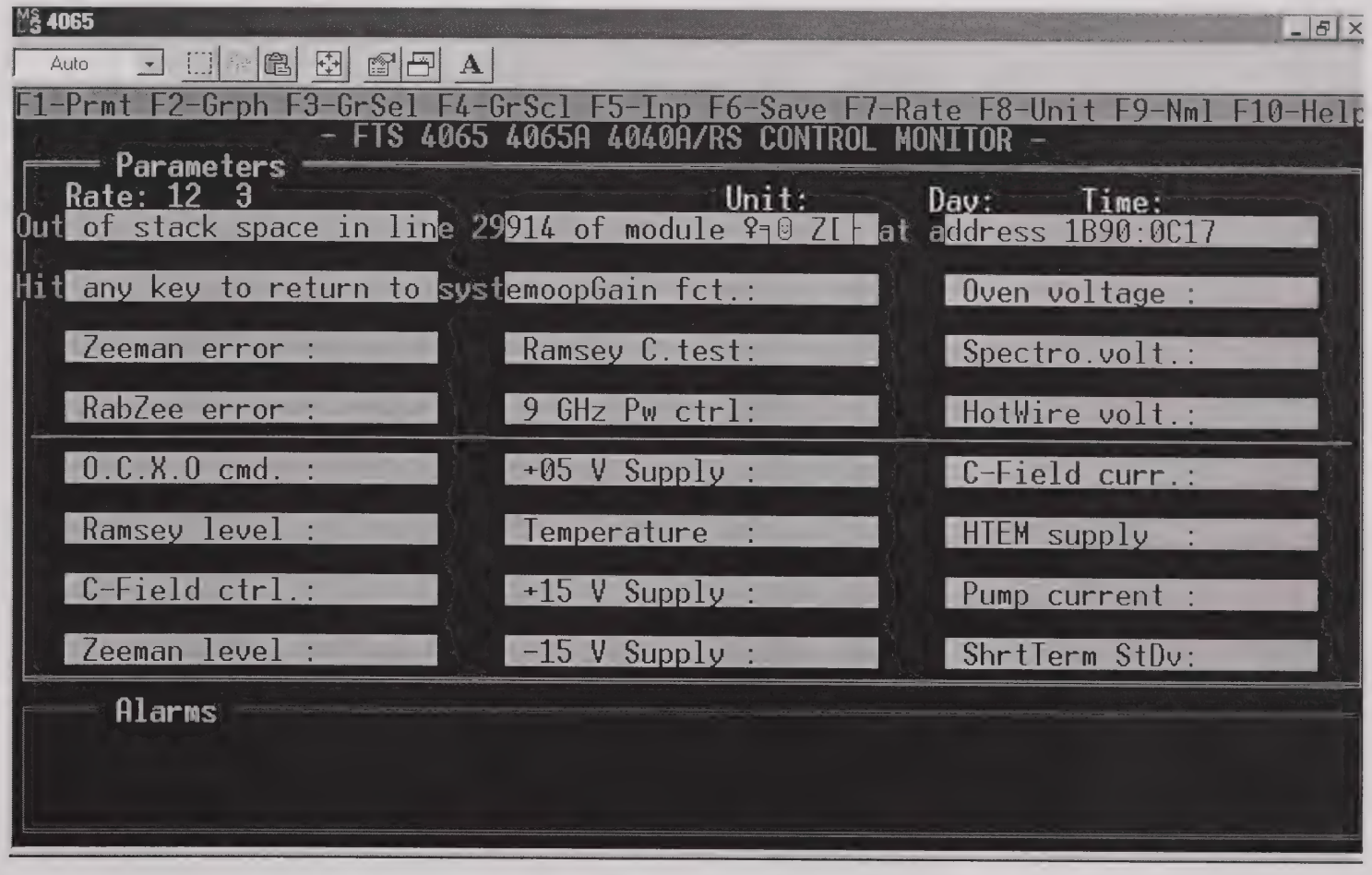
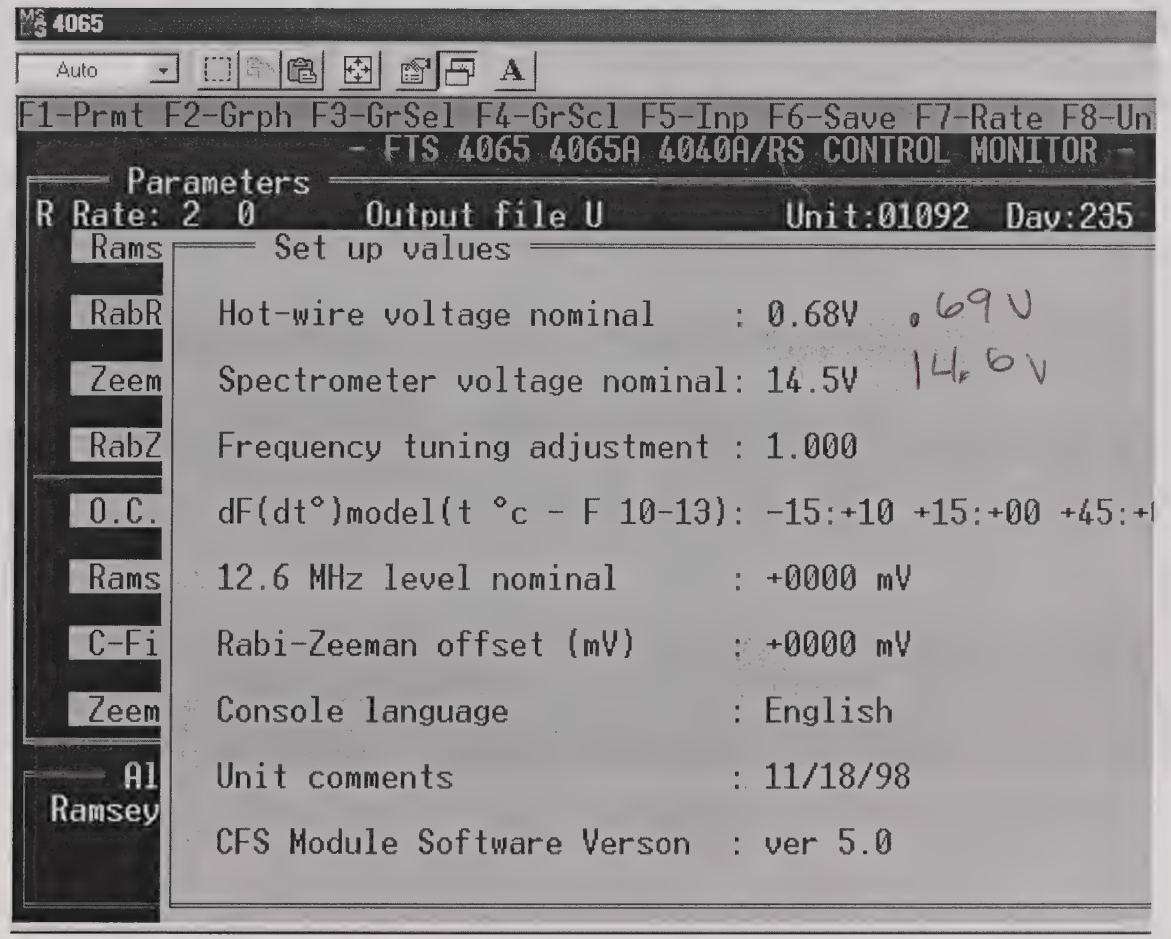
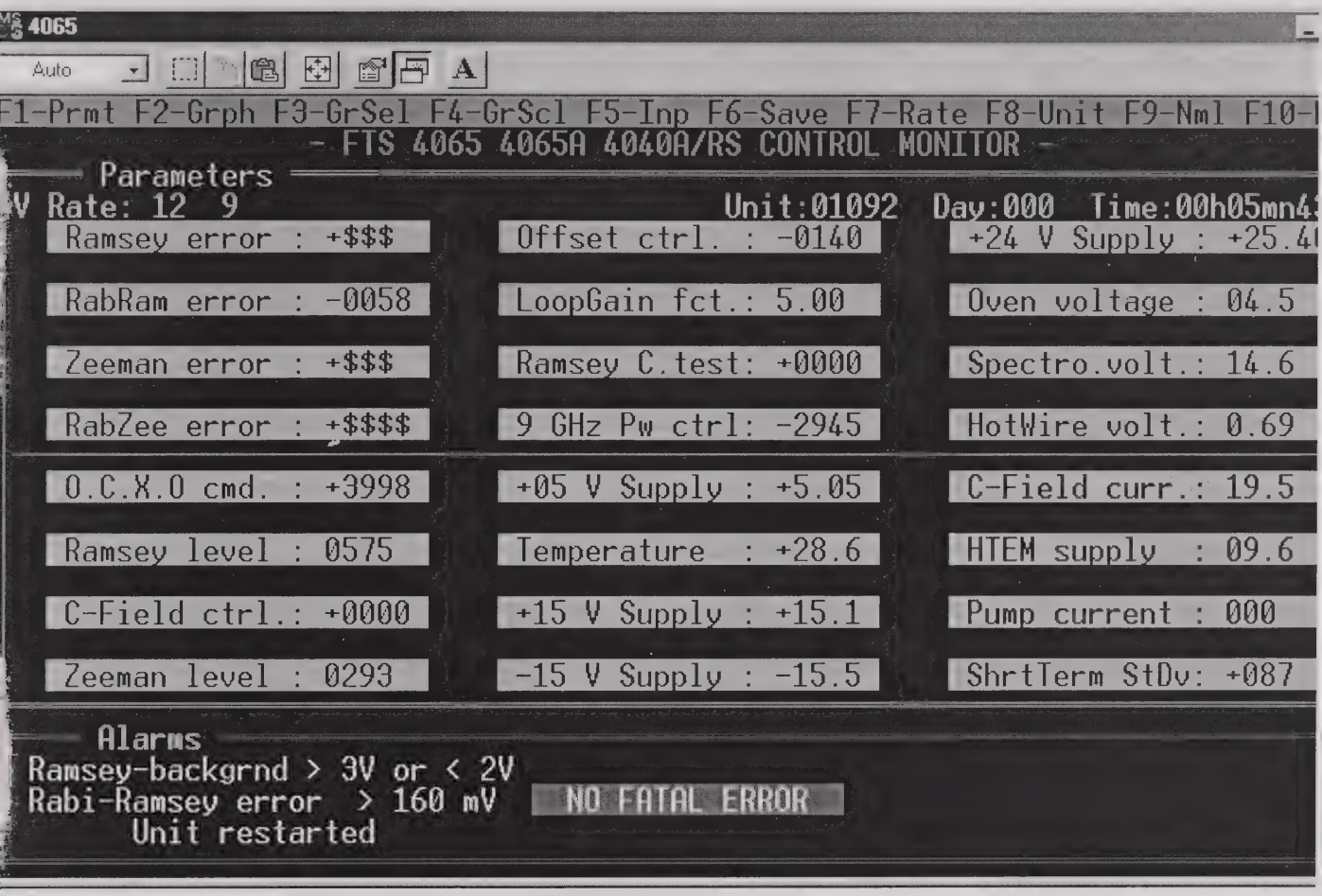


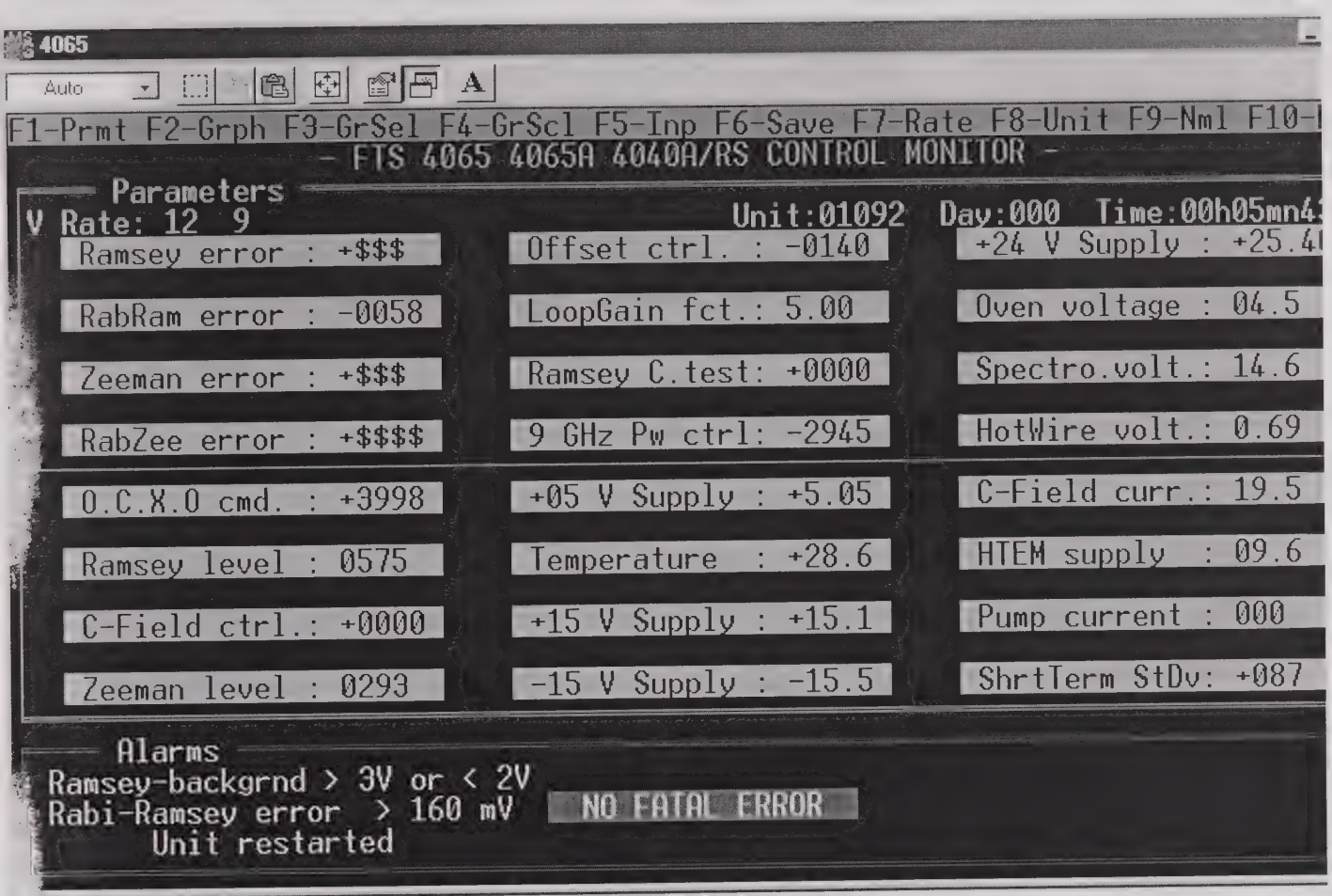
Figure E3 1 PPS SYNC FUNCTION

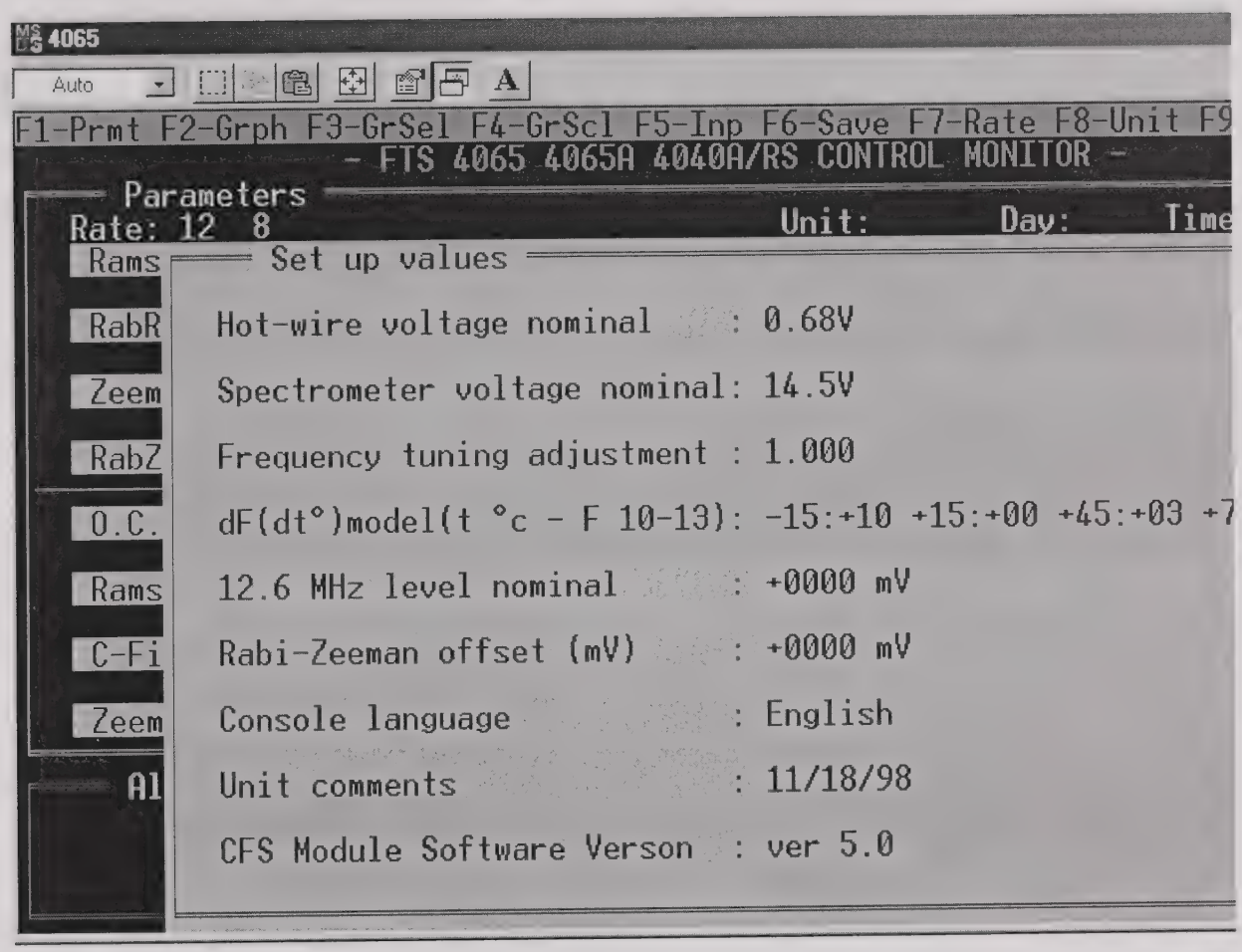

4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9-Nml F10-
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
Rate: 12 9
Unit:01092
Day:000 Time:00h05mn4
Ramsey error : +$$$
Offset ctrl. : -0140
+24 V Supply : +25.4
RabRam error : -0058
LoopGain fct.: 5.00
Oven voltage : 04.5
Zeeman error : +$$$
Ramsey C.test: +0000
Spectro.volt.: 14.6
RabZee error : +$$$$
9 GHz Pw ctrl: -2945
HotWire volt.: 0.69
O.C.X.O cmd. : +3998
+05 V Supply : +5.05
C-Field curr.: 19.5
Ramsey level : 0575
Temperature : +28.6
HTEM supply : 09.6
C-Field ctrl.: +0000
+15 V Supply : +15.1
Pump current : 000
Zeeman level : 0293
-15 V Supply : -15.5
ShrtTerm StDv: +087
Alarms
Ramsey-backgrnd > 3V or < 2V
Rabi-Ramsey error > 160 mV
NO FATAL ERROR
Unit restarted

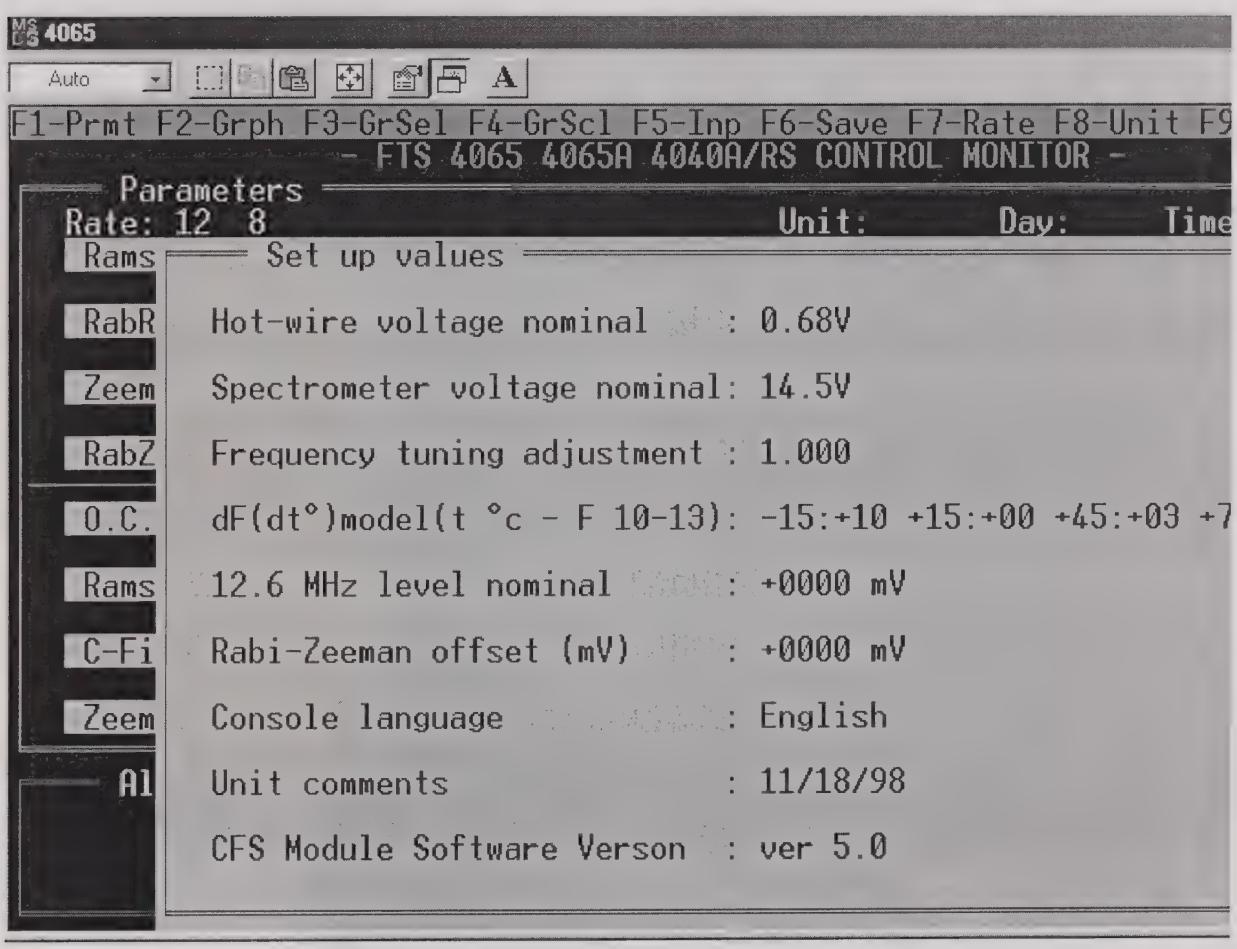

4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9-Nml F10-Help
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
Rate: 12 3
Unit:
Day:
Time:
Out of stack space in line 29914 of module ♀¬☺ ZI├ at address 1B90:0C17
Hit any key to return to systemoopGain fct.:
Oven voltage :
Zeeman error :
Ramsey C.test:
Spectro.volt.:
RabZee error :
9 GHz Pw ctrl:
HotWire volt.:
O.C.X.O cmd. :
+05 V Supply :
C-Field curr.:
Ramsey level :
Temperature :
HTEM supply :
C-Field ctrl.:
+15 V Supply :
Pump current :
Zeeman level :
-15 V Supply :
ShrtTerm StDv:
Alarms


4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Un
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
R Rate: 2 0 Output file U Unit:01092 Day:235
Rams
RabR
Zeem
RabZ
O.C.
Rams
C-Fi
Zeem
Al
Ramsey
Set up values
Hot-wire voltage nominal : 0.68V .69V
Spectrometer voltage nominal: 14.5V 14.6V
Frequency tuning adjustment : 1.000
dF(dt°)model(t °c - F 10-13): -15:+10 +15:+00 +45:+
12.6 MHz level nominal : +0000 mV
Rabi-Zeeman offset (mV) : +0000 mV
Console language : English
Unit comments : 11/18/98
CFS Module Software Verson : ver 5.0


4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9-Nml F10-
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
V Rate: 12 9
Unit:01092 Day:000 Time:00h05mn4
Ramsey error : +$$$
Offset ctrl. : -0140
+24 V Supply : +25.4
RabRam error : -0058
LoopGain fct.: 5.00
Oven voltage : 04.5
Zeeman error : +$$$
Ramsey C.test: +0000
Spectro.volt.: 14.6
RabZee error : +$$$$
9 GHz Pw ctrl: -2945
HotWire volt.: 0.69
O.C.X.O cmd. : +3998
+05 V Supply : +5.05
C-Field curr.: 19.5
Ramsey level : 0575
Temperature : +28.6
HTEM supply : 09.6
C-Field ctrl.: +0000
+15 V Supply : +15.1
Pump current : 000
Zeeman level : 0293
-15 V Supply : -15.5
ShrtTerm StDv: +087
Alarms
Ramsey-backgrnd > 3V or < 2V
Rabi-Ramsey error > 160 mV
NO FATAL ERROR
Unit restarted


4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9-Nml F10-
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
V Rate: 12 9
Unit:01092
Day:000
Time:00h05mn4
Ramsey error : +$$$
Offset ctrl. : -0140
+24 V Supply : +25.4
RabRam error : -0058
LoopGain fct.: 5.00
Oven voltage : 04.5
Zeeman error : +$$$
Ramsey C.test: +0000
Spectro.volt.: 14.6
RabZee error : +$$$$
9 GHz Pw ctrl: -2945
HotWire volt.: 0.69
O.C.X.O cmd. : +3998
+05 V Supply : +5.05
C-Field curr.: 19.5
Ramsey level : 0575
Temperature : +28.6
HTEM supply : 09.6
C-Field ctrl.: +0000
+15 V Supply : +15.1
Pump current : 000
Zeeman level : 0293
-15 V Supply : -15.5
ShrtTerm StDv: +087
Alarms
Ramsey-backgrnd > 3V or < 2V
Rabi-Ramsey error > 160 mV
NO FATAL ERROR
Unit restarted


MS DOS 4065
Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
Rate: 12 8
Unit:
Day:
Time
Rams
RabR
Zeem
RabZ
O.C.
Rams
C-Fi
Zeem
A1
Set up values
Hot-wire voltage nominal : 0.68V
Spectrometer voltage nominal: 14.5V
Frequency tuning adjustment : 1.000
dF(dt°)model(t °c - F 10-13): -15:+10 +15:+00 +45:+03 +7
12.6 MHz level nominal : +0000 mV
Rabi-Zeeman offset (mV) : +0000 mV
Console language : English
Unit comments : 11/18/98
CFS Module Software Verson : ver 5.0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Auto
F1-Prmt F2-Grph F3-GrSel F4-GrScl F5-Inp F6-Save F7-Rate F8-Unit F9
- FTS 4065 4065A 4040A/RS CONTROL MONITOR -
Parameters
Rate: 12 8
Unit:
Day:
Time
Rams
RabR
Zeem
RabZ
O.C.
Rams
C-Fi
Zeem
Al
Set up values
Hot-wire voltage nominal : 0.68V
Spectrometer voltage nominal: 14.5V
Frequency tuning adjustment : 1.000
dF(dt°)model(t °c - F 10-13): -15:+10 +15:+00 +45:+03 +7
12.6 MHz level nominal : +0000 mV
Rabi-Zeeman offset (mV) : +0000 mV
Console language : English
Unit comments : 11/18/98
CFS Module Software Verson : ver 5.0

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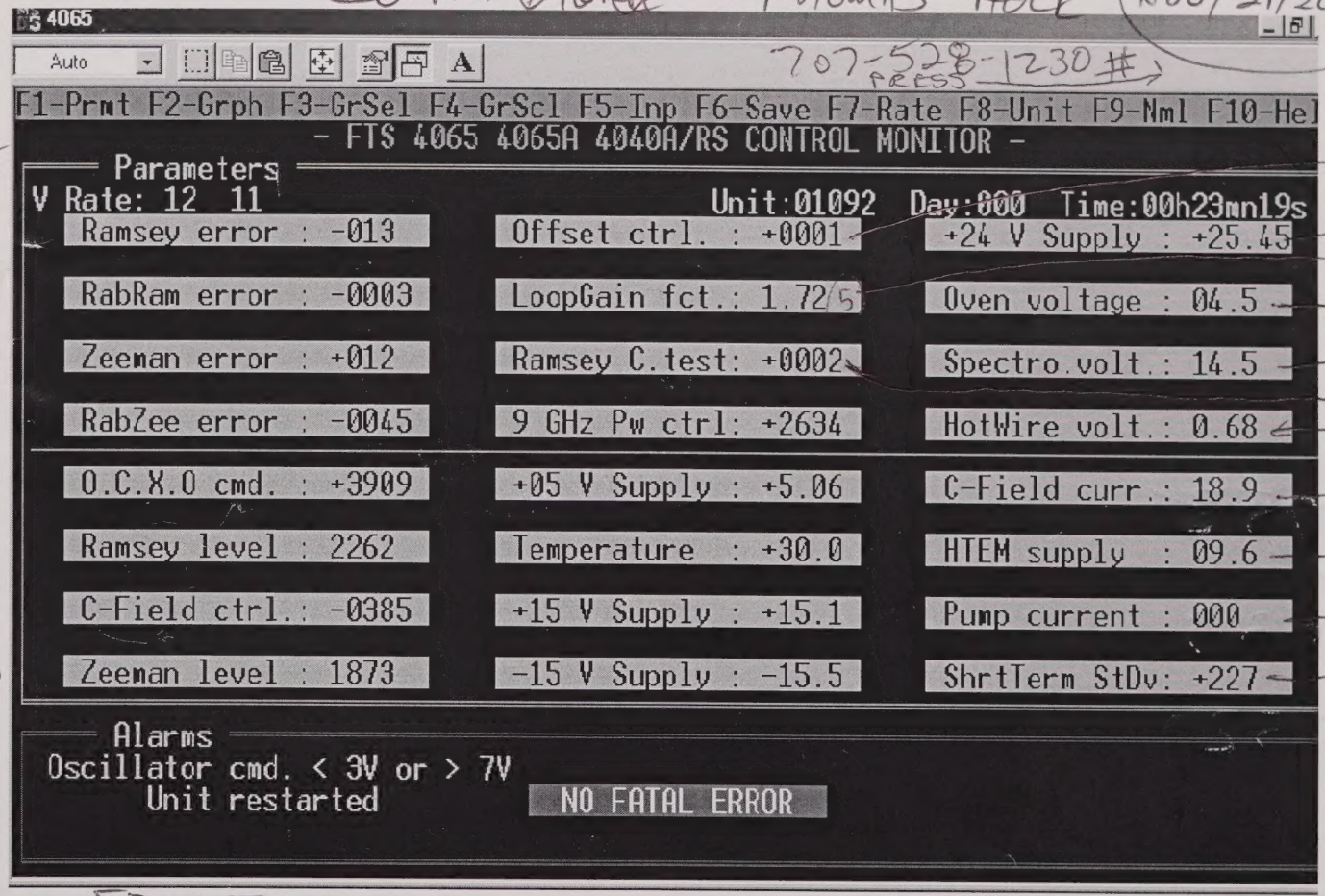

DEFAULT

400

200

400

200

8000

1000

8000

1000

8000

24V

5

5

10

CTEST 200

.75

10

10

100

500

FRONT

FTS 4040A

WARANTY S/N 01092

ELECTRONIC 9/30/02

TUBE 9/30/02

BACK

MODEL 4040A/RS

PART # 08832-505

→ DSI FAULT

~~or~~ FATAL ERROR

,000,000,100

1752

6033

1752

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